

**DEVELOPING A MEASURE TO BETTER UNDERSTAND THE
HANDEDNESS SKILL LEVELS FOR DESIGNING SIMULATION-BASED
SYSTEMS**

**A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
ATILIM UNIVERSITY**

**BY
BURAK GÖKBERK EYÜBOĞLU**

**IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE
DEGREE OF**

MASTER OF SCIENCE

**IN
THE DEPARTMENT OF COMPUTER ENGINEERING**

January, 2016

Approval of the Graduate School of Natural and Applied Sciences, Atılım University.

Prof. Dr. K. İbrahim Akman

Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof. Dr. K. İbrahim Akman

Head of Department

This is to certify that we have read the thesis “Developing A Measure To Better Understand The Handedness Skill Levels For Designing Simulation-Based Systems” submitted by Burak Gökberk Eyüboğlu and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Asst. Prof. Dr. Nergiz E. Çağıltay

Supervisor

Examining Committee Members

Assoc. Prof. Dr. Murat Koyuncu

Asst. Prof. Dr. Nergiz Ercil Çağıltay

Asst. Prof. Dr. Çiğdem Turhan

Asst. Prof. Dr. Erol Özçelik

Asst. Prof. Dr. Gül Tokdemir

Date: 29.01.2016

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Name, Last name: Burak Gökberk Eyübođlu

Signature:

ABSTRACT

DEVELOPING A MEASURE TO BETTER UNDERSTAND THE HANDEDNESS SKILL LEVELS FOR DESIGNING SIMULATION-BASED SYSTEMS

Eyübođlu, Burak Gökberk

M.S., Computer Engineering Department

Supervisor: Asst. Prof. Dr. Nergiz Ercil Çađiltay

January 2016, 68 pages

The performances of right hand use and left hand use can be different from each other. People generally use one hand better than other. That's why they prefer this hand while making manual activities. Understanding their preference for right or left hand use is very significant while an individual has to make activities that skill is required such as endoscopic surgical operations or activities demanding to use both hand precisely. A better understanding of these cases will improve some issues like enriching and improving the quality of existing surgical education programs, especially, designing, improving and managing of simulation-based instructional technologies. In this scope, this study examines the experiments about right hand and left hand preference in the literature and investigates the performance differences between right and left hand use with an experimental case study. Accordingly, a scenario is designed to measure the right and left hand performance of individuals in an objective manner. Then, an experimental study is organized to better understand the affect of handedness on participants' performance for a two handed task. The results of this study show that, the left handed group performed the both handed task in a shorter time period when compared with the both handed group. Additionally, the both handed group make significantly more collision when compared with the left handed group. Finally, the right handed group makes significantly more collision when compared left handed group. Moreover, we found that preferred hand and hand skill level have an effect on performance. When the difficulties between two scenarios are compared, it is seen that the difficulty of task is also a factor of

performance. These results are expected to guide the curriculum designers and instructional system developers for the skill-related training programs to better organize their programs and to better guide the trainees to improve related skills.

Keywords –Instructional technologies, surgical education, simulation, handedness

ÖZ

SİMÜLASYON TABANLI SİSTEMLER İÇİN EL YETENEK SEVİYELERİNİ DAHA İYİ ANLAMAYI SAĞLAYAN ÖLÇÜ GELİŞTİRMEK

Eyübođlu, Burak Gökberk

Yüksek Lisans, Bilgisayar Mühendisliđi Bölümü

Tez Yöneticisi: Yrd. Doç. Dr. Nergiz Ercil Çađıltay

Ocak 2016, 68 sayfa

İnsanların sağ ve sol ellerini kullanım performansları farklılık göstermektedir. İnsanlar genellikle bir ellerini diđer ellerine oranla daha yüksek bir performans ile kullanmakta ve işlerini yerine getirirken o ellerini kullanmayı tercih etmektedirler. Özellikle yetenek gerektiren işlerde ve endoskopik cerrahi operasyonları gibi her iki ellerini de hassas bir şekilde kullanmaya yönelik yeteneklerin geliştirilmesi gerektiđi durumlarda insanların sağ ve sol el kullanım tercihlerini anlamak son derece önemlidir. Bu durumların daha iyi anlaşılması, mevcut cerrahi eğitim programlarını zenginleştirmek ve iyileştirmek amacıyla, özellikle simülasyona dayalı yüksek bilişim teknolojilerinin kullanıldıđı sistemlerin tasarlanması, geliştirilmesi ve yönetilmesi konusunda önemli katkılar sağlayacaktır. Bu kapsamda bu çalışma ile insanların sağ ve sol el tercihleri ile ilgili yapılan çalışmalar alanyazından incelenmekte ve bir deneysel durum çalışması ile insanların sağ ve sol el kullanımlarındaki performans farklılıkları incelenmektedir. Bu araştırmanın sonuçlarının simülasyon tabanlı cerrahi eğitim teknolojilerinin tasarlanması ve geliştirilmesi konularında çalışan kişilere katkı sağlaması hedeflenmektedir. Bu nedenle, kişilerin sağ ve sol el performanslarını objektif bir yöntem ile ölçmek için bir senaryo tasarlanmıştır. Sağ elli, sol elli ve çift elli katılımcıların çift el gerektiren görevlerdeki performans farklılıklarını daha iyi anlamak için bir deneysel çalışma geliştirmiştir. Bu çalışmanın sonuçlarına göre; solak katılımcılar, çift elli katılımcılara göre iki elli görevi daha kısa süre içinde tamamlamıştır. Ek olarak, çift elli grup, sol elini kullanan gruba göre istatistiksel olarak daha fazla hata yapmıştır. Son olarak ise, sağ elli kullanan katılımcılar sol elini kullananlara göre istatistiksel

olarak daha çok hata yapmıştır. Tercih edilen elin ve el yeteneđi seviyesinin performansa etkisini gözlemledik. İki senaryonun zorluk seviyesini karşılaştırdığımızda ise senaryo zorluk seviyesinde performansı etkilediđi ortaya çıktı. Bu sonuçların müfredat tasarımcılarına ve öğretim sistemleri geliştiricilerine yetenek odaklı eğitim programları geliştirilmesinde programlarını daha iyi düzenlemesinde ve öğrencilerin ilgili yeteneklerinin geliştirilmesi için rehberlik etmesi beklenmektedir.

Anahtar Kelimeler –Öğretim teknolojileri, cerrahi eğitim, simülasyon, sağ ve sol el kullanımı

To My Family

ACKNOWLEDGMENTS

This study is conducted for endoneurosurgery education purposes as part of a project named ECE (112K287) supported by TÜBİTAK 1001 for three years (2011 – 2014). I would like to thank for the support of TÜBİTAK 1001 program for realizing this study.

I would like to express my sincere appreciation to my supervisor Asst. Prof. Dr. Nergiz Ercil ÇAĞILTAY for her continuous support, guidance and insight throughout my thesis study. I offer sincere thanks for her extensive knowledge, enthusiasm and patience during this period. I'm really proud of being one of her students.

I would also express my appreciation to examination committee members; Asst. Prof. Dr. Çiğdem TURHAN, Assoc. Prof. Dr. Murat KOYUNCU, Asst. Prof. Dr. Erol ÖZÇELİK, and Asst. Prof. Dr. Gül TOKDEMİR for their valuable time, comments and suggestions.

Last but not the least; I would like to express my appreciation to my family for their endless love, support and patience. They have always believed in me and encouraged me all through my life.

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CHAPTER 1

INTRODUCTION

Human side preference is one of the most significant subject about brain lateralization. Handedness, footedness, earedness and eyedness are the common examples of human side preference. Handedness is the most important and the most investigated subject about functional lateralization and asymmetries [1] [2].

The most straightforward definition of handedness is that it is a preference while performing a single hand needed task. Human handedness is generally classified with writing hand. A person who writes texts with right hand called right-handed. On the other hand, a person who write texts with left hand called left-handed. Handedness is the most important subject in medical actions such as surgical operations and surgical education. Furthermore, haptic devices are used in surgical operations like minimally invasive surgeries. The aim of this study is better understand the performance differences between right hand, left hand and both hands in single handed and double handed tasks.

1.1 Background of the Problem

Criteria for handedness as writing hand is insufficient. According to the literature, there are some ways of handedness classification. This classification can include some tasks and it can be branched for selecting different main tasks. This study offers a new handedness classification method. The target groups of this classification method are surgeons and surgical students because they have to use some minimally invasive surgery tools. Moreover, they have to use their both hands

equally well. The main reason of this study is understand the performance differences between a person's dominant and non-dominant hand.

1.2 Research questions

The purpose of this study is to find acceptable answers for two questions given below;

How to understand the handedness of participants in an objective way?

What is the affect of handedness on both handed tasks?

1.3 Significance of the study

The important thing about this study is that it is providing a handedness classification for surgeons, analyzing the performance differences between handedness groups as well as the performance differences between dominant-hand and non-dominant hand.

1.4 Limitations of the study

There are many restrictions of this study because implementing applications for haptic devices are difficult. For instance, it is hard to implement haptic device features like force-feedback and tactile sense. Furthermore, this also requires 3D generated objects.

This thesis is organized as follows: Chapter 2 covers the background of the study, Chapter 3 describes the research methodology used in this study. Chapter 4 details the results of the study and finally discussions and conclusion part of the study is provided in Chapter 5.

CHAPTER 2

BACKGROUND OF THE STUDY

In this study, the effect of handedness (left handed, right handed or both handed) on performance of both-handed tasks on a computer-based simulation environment which is developed for surgical training purposes is researched. Accordingly, in this chapter the related literature about the human side-preferences, hand preferences and performance and haptic devices that are used on skill-based research studies are summarized. Finally a summary of the literature is provided.

2.1 Human Side Preference

Studies about human side preference have been investigated for many years. The instances of side preference can be counted as handedness, footedness, eyedness, and earedness. The flake remains [3] and the stencils [4] used in cave art from the Paleolithic age are the historical example of human hand preference [5]. The 35,000 year-old Neanderthal remains and 500,000 year-old hominid remains are investigated, it was observed that the possibility of being right handedness of human is 93% in historical times [6].

Kicking a ball or standing on one foot are the examples of foot preference. The foot preference of an individual can affect the performance in sports [7]. It is well-known that there is less social pressure for foot preference than hand preference [8]. For this reason, right foot preference is lower than right hand preference in the population and the ratio of right foot preference is approximately 80% [9].

Eyedness is the preference while doing some activities require single eye. The preferred eye of using telescope is one of the examples of eyedness. About two third of human population prefer right eye while performing activities requiring one eye [10] [11]. Ear preference is preference when single ear needed activities like listening

to a conversation behind a closed door by placing ear to the door. The preference of ear called earedness. Earedness is the least investigated topic about lateralization preference. Studies about ear preferences show that right ear preference is 60% in the population [9].

Some studies found out that mixed handedness is one of the reasons for some neurodevelopmental and neurobehavioral disorders like schizophrenia [12] [13] and schizotypy [14] respectively. According to Uzoigwe, the hand preference is primarily caused by two reasons. First one is reducing the dependency duration of human offspring, and another reason is to make fight or flight reflex easier and speed it up [6]. Hand preference is not only determined by the skillfulness of the hand but also depends on the strength of the hand [6].

Nowadays, human hand preference can be classified as right handed and left handed by their writing hand. This classification method is very straightforward. However, it is insufficient. Since exact classifying is not always determined for human hand preference. For instance, an individual who use his/her right hand generally can prefer his/her left hand for doing some special activities. In other words, an individual who usually use left hand may prefer his/her right hand while using scissors. For this reason, it is possible to make a third classification of human hand preference which can be named as mixed-handedness in case an individual may not prefer his/her dominant-hand while operating a skill-requiring task. In other words, there is no priority order for this kind of people named as mixed-handed [15]. On the other hand, people who prefer both hands use their right hands for skill-requiring tasks, in other situations they use left hand and they use rarely both hands for the same tasks [16]. For instance, writing with right hand and throwing something to somewhere.

The term “Ambidexterity” can be used for people who use both right and left hand well equally. As a result of being ambidexterity means that there is no preferred or dominant hand when encountered this kind of manual activities [6]. Furthermore, some activities need the coordination between dominant hand which plays active role and non-dominant hand which plays supportive role [17]. As a result, during a dominant hand operating action, non-dominant hand supports dominant one [6].

Uzoigwe states that using both hands well are time consuming and can be vital when encountered problems [6]. On the one hand, a single handed has to defend himself when he realizes a danger, he takes spear his right hand and he takes club by his left hand immediately and there is no time delay caused of hand preference.

On the other hand, when an ambidextrous encounters with the same problem, s/he thinks and compares the performance of using right or left hand and only then acts. This thinking process introduces a time delay [6]. This kind of problems can cause injurious and fatal accidents [6]. According to Uzoigwe (2013), the risk possibilities of left handed are higher than right handed people [6]. Moreover, Uzoigwe also states that the percentage of suffering from an accident is higher for mixed-handed when compared to single handed [6].

Classifying human hand preference is related to both hand skill improvement and inborn. Researchers note that the development process of hand preference has been observed since infancy [18]. Campbell et al. assessed that babies prefer hand to grasp objects which are getting close to themselves. This preference is regarded as hand preference [19]. The result of this study showed that there is a dichotomy in hand preference when child is in between his 7th and 13th month [18][20][21] and hand preference is determined by the age of three.

Laland estimated the probability of having left-handed child for three different cases. First, the possibility of having left-handed child is 8% if the parents are both right-handed [22]. Second, 22% if at one is left-handed and other is right-handed [22]. Third, 36% if both parents are left-handed [22]. The probability of being left-handed child of left-handed mother and right-handed father is higher than right-handed mother and left-handed father [22]. This shows that gender-linked genetic factors have effects on handedness [23].

Moreover, imitating parents also plays an important role on handedness [24] [25]. Furthermore, the interaction between mother and child such as playing games, giving and receiving something is also plays significant role on child handedness [19]. For

instance, a left-handed mother provides her child for using his or her left hand as a result of interactions between mother and child [19] [26]. For this reason, being a left-handed child depends on left-handed mother [27] [26]. Right-handed mothers play with their right hand so hand preference of being right-handed will be strengthened. On the other hand, the usage of left-hand will weaken [25] [28]. This can be the reason of the small ratio of left-handed adults [19].

Studies show that there is no statistical differences on genders [16] and meta-analysis results show that the possibility of left hand preference is higher in males than females [29]. McManus et al. indicated that the number of genes determines at least thirty to forty and this number can increase up to hundred. However, there is no direct effect of genes and proteins on handedness [30]. On the other hand, it is known that genes have effect on development of related region of brain and other related structures [31]. Forrester et al. reported gestures, speech, tool use, two hand coordinated action, and body posture and standing on foot are evolutionary linked on right-handed populations [32]. After experiments were done, it is recorded that the hand preference patterns preschool child and great apes are similar to each other [32]. According to Forrester et al. (2013), hand preference is not a new or human-specific feature but handedness is a feature developed by tool use and it is a common inheritance for human and great apes [32].

Studies show that handedness on twins can be different. For example, one of them can be right-handed but other can be left-handed [16]. Moreover, hand preference of identical twins is more compatible than non-identical twins [33]. Handedness can be linked on several subjects like cognitive abilities [34], personality [35], motivation [36], perception [37], and language [38], depression [39] and schizophrenia [13] [40]. Furthermore, there are some evidence about medical situations like alcohol consumption [41] or breast cancer risk [42] can be related on handedness.

Annett investigated and observed there are different hand preference type for different activities like writing a text, throwing a ball, using scissors, threading the needle, sweeping, using a shovel, dealing playing cards, using hammer, brushing teeth, opening jars in her experimental studies [15]. In other words, people prefer different

hands while they are making different jobs [15]. Annett noted that distribution of hand preference is dependent for tasks that are related to different skills [15]. According to Annett (1970), hand preference is always accepted as continuous property and it can be changed by different situations.

Similarly, Tan & Tan examined that whether human hand preference can be predicted or not. The research was done in Turkey and the participants of this research were 327 newborns and 3974 adults. It is recognized that the distribution of right handed and left handed is nearly equal in newborns and adults [43]. However, the high ratio of mixed-handed in newborns is decreased greatly when they are getting older. This decreasing number is occurred because most of them prefer their right hand as hand preference [43]. This study examines that natural left-handed people had to prefer right hand due to cultural pressures [16].

2.2 Hand Performance and Preferences

Handedness is the most preferred subject about functional lateralization and asymmetries [1] [2]. When the distribution of handedness considered, the preference of right hand is very common and the percentage of right hand preference is over 90% [44] [45]. There are many researches about the performance differences between dominant and non-dominant hand use in the literature. However, there are very little research about the performance level of being right handed or left handed. Annett et al., stated that the non-dominant hand of participants needs more corrections and more movement times than the dominant hand due to non-dominant hand force production variability [46].

In 1970, Salvendy, reported that the performance of right handers are better than the performance of left handers when participants used their dominant hand [47]. Moreover, the study of Barnes and Mundel supports this thought that left handers was 8% slower than the right handers in specific tasks [48].

According to Hoffmann (1995), dominant hand was significantly faster and accurate than the non-dominant hand [49]. Especially, for the right dominant handed people,

there is a significant performance difference between dominant and non-dominant hands. However, this issue is not valid for the left handers [49].

On the other hand, Provins & Glencross made a research about handedness in typewriting and handwriting [50]. They tried to find out which hand preference is better than the other hand. They took care of total writing time, errors and correctness of written words, letters and tapping [50]. The participants of this experiment were typists and non-typists. As a result of two different researches, they came across with two different results. One of them is the result about handwriting, the dominant hands of participants are better than their non-dominant hand [50].

The other one is about typing; they encountered two different results for the typists because of typists and non-typists. For the trained typists, the left hands of participants were faster [50]. Moreover, the left hands of trained typist right handed typists are better than the performance of their dominant right hands [50]. On the other hand, non-typists have a greater performance on letter typing speed with their right hands than their left hand [50].

According to experiments done in 1995, Hoffman came across with three results about performance of right or left dominant hand success. First, there is no significant performance difference in right and left handers when they are using dominant hands [49]. Secondly, when non-dominant hand is used, the left handed people are more successful than right handed people [49]. The last but not least, there is a great performance difference between dominant and non-dominant hand [49].

Hoffmann and Halliday made an investigation about the learning and performance ability [51]. As a result of experiments, there was no difference between left handers and right handers in learning performance and learning ability. This results supports the study made by Salvendy and Seymour, because they have found that there was no significant difference between the performances of right and left handed workers [52]. Hoffmann and Halliday found out that left handers are as productive and creative as right handers in daily tasks.

According to the surveys, only eleven percent of Americans are left handed [52]. This shortage of left handedness is the main reason of the little number of medical staff such as surgeons [53]. According to studies indicated that left handed people have bigger risk of suffering some troubles[54] like, trauma [55], vehicle accidents [56], and injuries due to sports [57] than right handed people although left handed people are thought to be more talented in musical [58] and artistic [59][60] domains. The study of Adusumili et al., (2004) shows that left handed surgeons are trying to adapt to a right handed world [61]. Moreover, there is no material available to teach surgical techniques to left handed medical students [61]. According to Schueneman and Picklemann (1985), left handed surgeons are more sufficient on a difficult neuropsychological test of tactile and kinematic information [62]. On the other hand, they tend to be more careful, more sensitive to pressure and they have lesser operating skills when they compared to right handed surgeons [62]. Left handed surgeons found some difficulties to learn some surgical operations such as standing on the right side of the operating table, open cholecystectomy and pelvic surgeries [62]. Left handed surgeons also finds some difficulties in using some tools like long vascular needle holders, heavy hemostatic clamps, and right handed scissors. As a result of the study of Adusumilli et al., it is needed to develop tools and to create learning environments to resolve the disadvantages of left-handed surgeons [61].

Handedness can be considered as the most significant subject on hand skill based medical actions such as surgical operations and medical treatments. In these systems monitoring the skill level improvements is very critical and important. For instance for surgical training programs by monitoring the skill improvements of the trainees one can make an appropriate decision for continuing the training procedures and starting the practical training for further levels such as in the operating theater. Similarly, it is important to understand and measure the rehabilitation patients' improvements and treatment success levels.

On the other hand, there are not enough experimental studies for medical students' training. In medical faculties, these training procedures are given by the help of haptic devices. According to Acosta et al. (1999), haptic devices are the human computer interface technology that permits touch and manipulation of imaginary computer-

generated objects in a way that evokes a compelling sense of tactile realness [63]. It can be understood that haptic devices are used in medical education for two main reasons by the definition of Acosta [63]. One is force feedback and the other is tactile sense.

2.3 Haptic Devices

Haptic devices are used in minimally invasive surgeries such as total hip replacement surgeries [64], endoscopic surgeries [65], laparoscopic surgeries [66], cardiovascular surgery [67], and childbirth simulation [68] for the training of medical students. Furthermore, they are also used in medical education such as needle insertion [69], to understand the palpation feeling [70], and bone cutting [71]. Also, they are used for diagnosing disease like breast tumor cancer [72]. The studies discussed above that only using haptic device is inadequate but these training types also need virtual environment. According to these articles, it seems clearly that using haptic device in medical surgery training is beneficial for medical students by the help of virtual environments. In addition to this, haptic device are also used for rehabilitation patients who were suffered from brain injuries such as stroke [73], hemiplegia [73], and cerebral palsy [74] with the help of virtual environment.

2.4 Summary of Literature

There are many evidences that human hand preference is a congenital genetic characteristics and it is also related to some cognitive behaviors in the literature. The ratio of being right or left handedness in infants are generally close to the ratio of right or left handedness in adults. Moreover, hand preference can change during individual's lifetime. Studies found in the literature show that, there is no standardized side preference of human being. The studies in the literature show that hand preference and skill is dependent to each other. In other words the side preferences are changing based on different parameters such as the task being performed, the social perceptions, cultural affects, environmental factors and genetic factors. By analyzing the studies found in the literature, human hand preference can be classified by the following:

- Right handedness, people who use always right hand when doing actions needs one hand and they never use their left hand for operating these actions.
- Left handedness, people who use always left hand when doing actions needs one hand and they never use their right hand.
- Sometimes right handedness sometimes left handedness, people who are performing single hand actions by their right hand, for other single hand actions they use left hands for performing actions. For instance, a man writes with his right hand hammers with this left hand.
- Mixed-handedness is a type of people who use both hands equally well. They have no hand preference when they are operating single hand needed activities. For example, a man is writing with his both right and left hand legibly.

Additionally, from the literature it is understood that the hand preferences and skills of each hand are affective factors on the human performance on specific tasks. Accordingly, understanding the performance differences based on hand preferences and skill levels of each hand is important to improve the task performances. This is critical information for understanding the surgical skill levels and developing appropriate training programs. Hence this study aims to better understand the performance differences based on left hand, right hand and both-handed tasks.

As a result of this, in this study, the dimensions and causes of performance differences about using right hand, left hand and both hands are examined with the use of special haptic devices in simulation-based environment.

CHAPTER 3

RESEARCH METHODOLOGY

This study is aimed to better understand the affect of handedness on two handed task performance. The results of this study expected to guide the endoscopic surgery training program designers to better understand the candidate surgeons' skills and develop the educational materials accordingly. In other words, the aim of this study is to understand the performance differences based on the handedness of the participants. As a result of the literature review, it is understood that people may prefer different hands for different tasks such as writing a text, throwing a ball, using scissors, threading the needle, sweeping, using a shovel, dealing playing cards, using hammer, brushing teeth, opening jars. For instance, a person may use his/her left hand while writing a text, whereas s/he uses his/her right hand while throwing a ball [15]. In some cases, participants may use their non-dominant hands more effectively than their dominant hands. Moreover, a left-handed participant can use his/her right hands better than his/her left hands. Accordingly, their hand skill levels vary for left and right hand which is an affective factor for the endoscopic surgery skills that both hand performance is critical. Thus this study is conducted to better understand the performance differences between right and left hands and their effects on both handed tasks. In this chapter, the research method and materials are explained in detail.

3.1 Research Questions

The studies found in the literature show that the skill levels of people for their left hand and right hand is changing from person to person and even in time for the same person. However in the literature there is no objective measure to understand the skill level differences between left and right hands. Accordingly in this study first the handedness of the participants will be examined and then the effect of handedness on

both-handed tasks will be examined. Hence the research questions of the study are set as below:

RQ1: How to understand the handedness of participants in an objective way?

RQ2: What is the effect of handedness on both handed tasks?

3.2 Research Procedure

In this study in order to answer the above research questions, we have conducted an experimental study including simulation-based scenarios. In the first scenario which was called “Using Haptic Device”, it is aimed to classify participants for their hand preferences and understand their handedness. In this scenario, the participants are given tasks to complete using their dominant and non-dominant hands. In order to understand the effect of handedness on tasks requiring both hands, “Wire Haptic in Dark” game is utilized. The participants played this scenario with their both hand, under the condition of a dark scene. After the experiment, quantitative data was collected for each task, such as time, distance, number of errors (i.e. collisions) and success ratios of the participants for each task. These surgical simulation games were developed as a part of Endoneurosurgery Education Project (ECE) supported by TUBITAK. The scenarios used in this study can be listed as follows:

1. Using Haptic Device- (with Dominant Hand)
2. Using Haptic Device- (with Non-dominant Hand)
3. Wire Haptic in Dark- (with Both Hands)

The order of research procedure of this study is shown in Figure 3.1. As seen in Figure 3.1, in order to better understand the handedness of the participants, the “Using Haptic Device” scenario results and the handedness questionnaire results were analysed as well as the studies found in the literature. Furthermore this information was used to better understand the participants’ handedness on their performance for the Wire-haptic in Dark scenario.

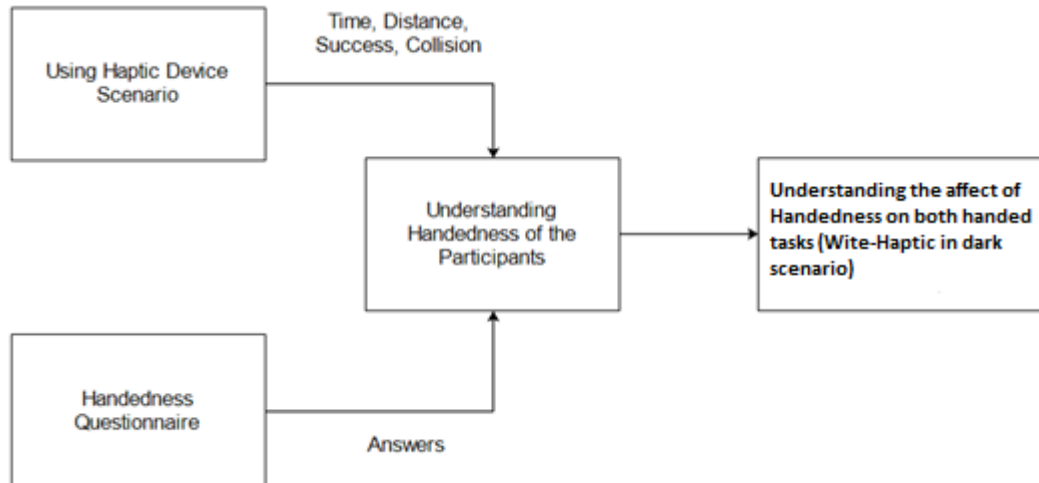


Figure 3.1 – Research Procedure

The experiments took place in a computer laboratory in both universities (Atılım University and Hacettepe University) using the same tools (computer, monitor, haptic devices, etc.). The candidate surgeons from the Hacettepe University Medical School and graduate students at the Atılım University have participated in this study. Steps of the experiment are explained below:

1. At the beginning, participants were asked to fill out a form including their personal information, age and department.
2. Starting with the first scenario, “Using Haptic Device”, participants were given tasks that they performed first with dominant and then non-dominant hand (or vice versa). In order to balance the dominant hand and non-dominant hand order, the first participant started the study with his/her dominant hand, where the second participant started with his/her non-dominant hand. The scenario consisted of 10 tasks and had a time limit for each task independently. Time, distance, success and collision were measured automatically by the computer system to understand the handedness of the participants.

Time: The required time taken to perform this single-handed scenario is called time. Time is kept in seconds.

Distance: The magnitude of covered path to perform this scenario is called distance and the unit of distance is pixels.

Success: Success is the ratio of true touches of the numbers given in the scenario.

Collision: Collision is the ratio of wrong touches while participants were performing the tasks in the scenario.

3. At the second step, Wire Haptic in Dark game was played by the participant by using their *both hands*. Hence, one haptic was used as the light source (endoscope) in the scene. Time, success and number of collisions were stored automatically by the computer system in this scenario.

Time: The required time taken to perform this both handed scenario is called time. Time is kept in seconds.

Success: Success is the ratio of non-touched moves through the wire to reach the target point.

Collision: collision is the ratio of touches between wire and tool while participant were performing this scenario.

4. After the experiment the participants were asked to fill out the questionnaire of Handedness Survey (see Appendix A). This questionnaire was prepared to better understand participants' hand preferences when performing some actions. This questionnaire had some 3-choice items as well as some open ended items. The questionnaire is adopted from Annett's Handedness survey [15] (see Appendix B).

Participants were given 30 minutes for the experimental part of this study. Detailed explanation about the scenarios used in experimental study will be given in "Instrument- Scenarios in the Experimental Study" section.

3.3 Participants

28 surgeons (21 doctors and 7 interns) from the Department of Neurosurgery or Otolaryngology in Hacettepe Medical School and 4 software/computer engineering graduate program students in Atılım University participated in this study. Detailed information about participants for the experiment is shown in Table 3.1.

Table 3.1 –Participants of the Experiment

Department	Gender		
	F	M	Total
Hacettepe Uni. Neurosurgery	1	11	12
Hacettepe Uni. Otolaryngology	3	6	9
Hacettepe Uni. Neurosurgery Interns	2	5	7
Atilım Uni. Computer Eng (M.Sc/Ph.D)	1	1	2
Atilım Uni. Software Eng (M.Sc/Ph.D)	1	1	2
Total	8	24	32

3.4 Instrument- Scenarios in the Experimental Study

In this study, firstly, using “Haptic Device Scenario” was performed two times with participant’s dominant and non-dominant hand to understand the hand preference of participants. Then using both hands in the dark scenario was performed by each participant. The aim of this scenario is to understand the affect of handedness on participants’ performance while performing tasks requiring both-handed skills.

The detailed explanations and activity diagrams of the scenarios are given in the following section.

3.4.1 Using Haptic Device Scenario

This scenario was applied by the participants to comprehend the performance differences between using dominant and non-dominant hand. At the end of this scenario, the hand preferences of participants is decided. The general layout of the first scenario of the experiment is shown in Figure 3.2.



Figure 3.2 –Using Haptic Device Scenario

Firstly, observer has to write participant's id and should record the hand information using the checkbox on the interface (whether the participant is starting with the dominant or non-dominant hand).

At the beginning of the experiment, the participant should calibrate the haptic device. The participant has to move the haptic device backwards, until circle fits adjusting circle. As seen from Figure 3.3, when circle fits adjusting circle, experiment starts.



Figure 3.3 –Haptic Calibration Screen

After the calibration step, the participant will encounter a table which includes numbers from 1 to 9 in an unarranged order and endoscopic tool figure. The participant has to touch the endoscopic tool figure and the number which is written on the top right corner of the screen with the help of the haptic device movements in given time. The time limit is 7 seconds for each task.



Figure 3.4 –A Successful Task Example

If the participant touches the correct number on time as shown in Figure 3.4, then the task is completed successfully and he/she continues with the next number until the whole 10 tasks end. However, if endoscopic tool does not touch the given number in the given time, the task will be counted as failure as shown in Figure 3.5 and the experiment continues with the next number.



Figure 3.5 –A Failed Task Example

When the participant finishes ten consecutive random numbers, the first step of experiment is completed. In addition to this, the participant has to perform this experiment with his/her other hand. At the end, the statistical details of the experiment is recorded including the time, distance, number of errors and the success of the task. Activity diagram showing the procedure for one task of this experiment is given on Figure 3.6 below.

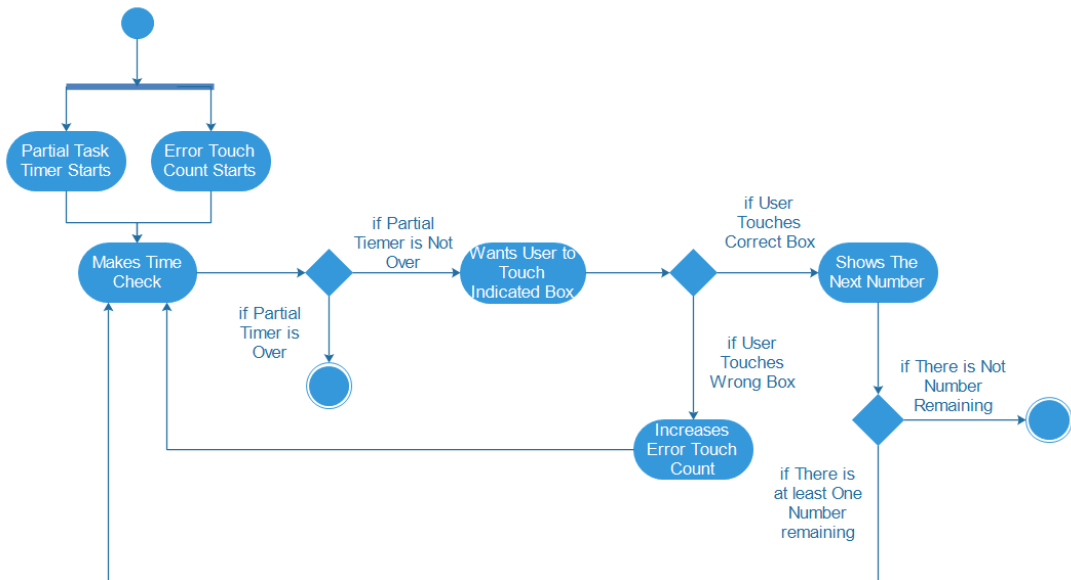


Figure 3.6 –Activity Diagram for Using Haptic Device Scenario

3.4.2 Wire Haptic in Dark Scenario

In this scenario, participants have to pass the ring without touching the wire. This scenario is performed in the dark unlike the other activity. The participant's id and code will be entered to the text boxes. The scenario starts by clicking the start button when the participant is ready. The success of the participant will be calculated with the help of collision count and time taken to finish the scenario.

The controls of light and stick will be supplied by the movements of non-dominant and dominant hands respectively. The general layout of this scenario is provided at Figure 3.7.



Figure 3.7 –The General Layout of Using Both Hands in the Dark

The participant controls the ring by the movements of his/her dominant hand and he/she controls the light by the actions of his/her non-dominant hand. For instance, a right-handed participant controls the ring with his right hand. Moreover, participant controls the light with his/her left hand. Figure 3.8 shows that a participant is climbing upwards on the wire.

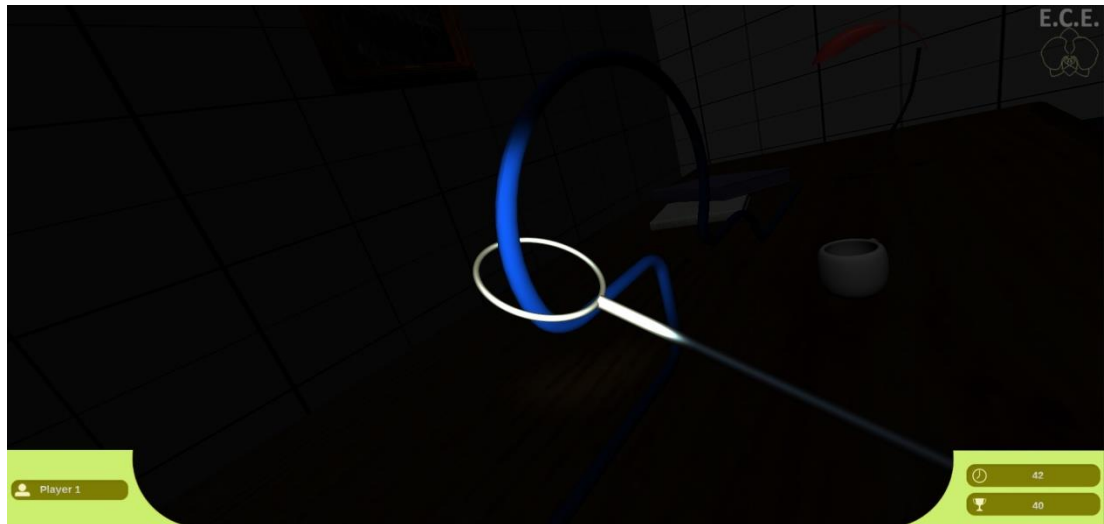


Figure 3.8 –A moment of a Participant’s Trial

When the wire and the ring touch, a ball appears at the point of contact. The participant has to wait three seconds at the location of the ball. Figure 3.9 shows the point of collision and participants have to wait three seconds without touching the wire and the ring which is at the end of the stick.

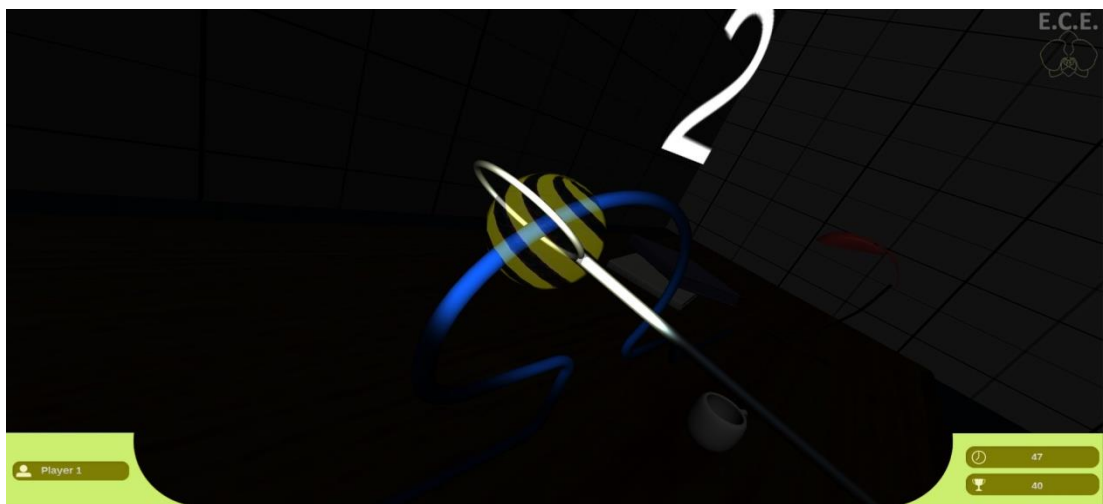


Figure 3.9 –Participant’s collision

Activity diagram that shows and explains the main procedure is given on Figure 3.10.

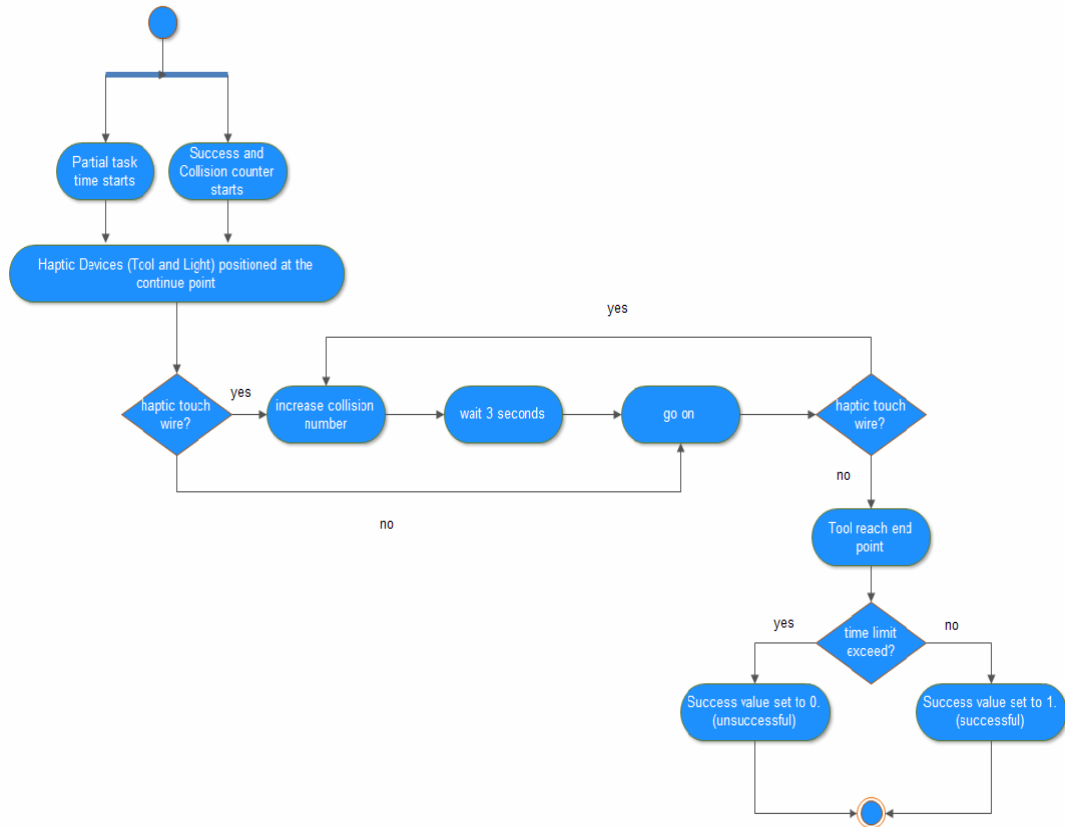


Figure 3.10 –Activity Diagram of Using Both Hands in the Dark

3.5 Handedness Survey

Participants were also given a survey that includes some single-handed tasks and they had to indicate the preferred hand to perform in listed action. In order to see all actions listed in handedness survey, see Appendix A. This survey was translated and adopted from English to Turkish. The original form of survey was written by Annett in 1970 (see Appendix B) [15].

3.6 Measures of the Study

In this study, in order to better understand the participants' performance in the prepared scenarios some measures were recorded automatically by the computer system. These measures are explained in detail for each scenario below.

3.6.1. The measures collected in “Using Haptic Device” Scenario

Time is the duration of task performed by the participant’s single hand. Time information is kept in seconds. Time is one of the measures that specifies handedness. For instance, if the time of a participant with right hand is less than the time with left hand, it can be said that participant uses his/her right hand faster and this participant is right-handed.

Distance is the length of covered path to achieve using haptic device scenario. Distance is kept in pixels. While specifying the dominant hand of a participant, distance of right hand and distance of left hand should be compared. The dominant hand can be determined by less distance because people find shorter paths when doing single-handed tasks with their dominant hands.

Success is the third measure of “Using Haptic Device” scenario. Success is the ratio of true touches while performing this scenario. Success is also a measure that specifies handedness. More success ratio with right hand means the participant is right handed.

Finally, **collision** is also one of the measures of “Using Haptic Device” scenario. Collision is the wrong touches of the participant. In order to understand the handedness of a participant, the collision ratios of right and left hands should be compared. Then the hand with a smaller collision ratio is determined as the dominant hand.

3.6.2. The measures collected in “Wire Haptic in Dark” Scenario

Time is one of the measures of “Wire Haptic in Dark” scenario and time is kept in seconds. Time is the duration of performing this scenario with both-hands. This measure is created to understand the affect of participant’s performance while performing both-handed tasks. The shorter time can bring higher performance but success and collision are also taken into consideration.

Success is the second measure of wire haptic in dark scenario. Success information is kept by percentages of every step in this scenario. High success ratio with less collision ratio brings high performance while performing this scenario.

Collision is the last but not least measure of evaluation of the handedness performance on both-handed task. Collision information of a participant is kept by percentage of every step in the scenario. Collision is the number of touches of tool and wire. The less collision amount brings higher performance while performing both-handed tasks.

CHAPTER 4

RESULTS

4.1. Understanding Subjects' Handedness

“Using Haptic Device” scenario was used to understand the handedness of subjects. At the end of the experiment, we realized handedness of each participant showing which hand of participant is more skilled than the other. For instance, a right-handed participant may get better results with his/her left hand. As a result of this, we derived a formula to understand the handedness of each participant. As in Formula 1 is set to calculate the performance of single hand as in the following;

$$Performance_{Hand} = \frac{Success_{Hand}}{Time_{Hand} * Distance_{Hand} * Collision_{Hand}}$$

Formula 1 – Calculating the Performance of Single Hand

The performance of hand is calculated by the relationships of four data. These are the percent of successful touch, the time required for performing this scenario, the distance that needs to complete the scenario given by the haptic device and the ratio of the collision touches. Hand performance is directly proportional to success. On the other hand, required time, discovered distance and the collision ratio are inversely correlated. It can be clearly understood that as a result of using this formula, we came across some mathematical undefined cases that can be called a number divided by zero ambiguity. For instance, a participant completes this scenario without collision, we had to encounter with this ambiguity.

After these uncertainties, we realized that we had to normalize the collision ratio with the help of Formula 2.

$$NewCollison_{Rate} = (1 + Collison_{Hand}) * 100$$

Formula 2 – Avoiding Collision Formula

With the help of this normalization, hand performance is calculated by the help of Formula 3 as follows:

$$Performance_{Hand} = \frac{Success_{Hand}}{Time_{Hand} * Distance_{Hand} * NewCollison_{Hand}}$$

Formula 3 – Normalized Formula of Calculating the Performance of Single Hand

After this formula, it is needed to understand which hand is better than the other. The process of understanding which hand is better than the other is calculated in three steps. First, this formula is applied to the right hand named $Performance_{RightHand}$. Secondly, this formula is applied to left hand named $Performance_{LeftHand}$. Finally, subtract $Performance_{LeftHand}$ from $Performance_{RightHand}$. After subtraction, if the value is greater than zero, the hand preference of participant is right. On the other hand, if the value is smaller than zero, the participant is left handed for this task. There is also one more case where the result value is zero. Furthermore, if the value is zero or close to zero, participant is regarded as both-handed. In other words, it can be said that the participant can use both hands to perform this scenario by making no preference. When our solution is applied to the results of this experiment, the handedness distribution of participant is specified. The handedness distribution of participants according to using haptic device scenario is shown in Figure 4.1. As illustrated in Figure 4.1, there are 15 left-handed people (50%), 9 right-handed people (30%) and 6 both-handed (20%) people who participated in our experiment. The results of two participants were eliminated because of the haptic device problems.

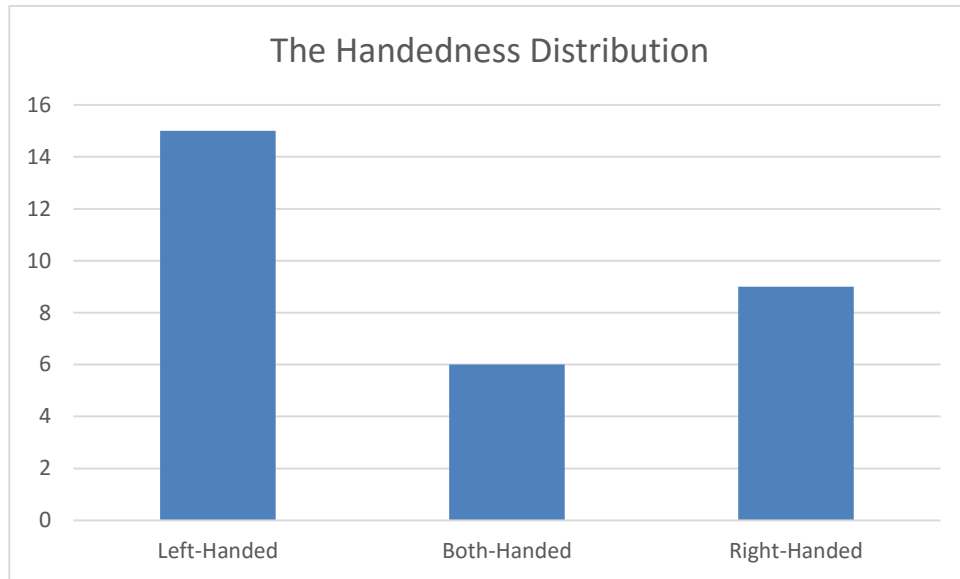


Figure 4.1 –The Handedness Distribution of Using Haptic Device Scenario

Additionally, the standard deviation and means of Using Haptic Device Scenario for left, right and both handed groups are analyzed. There are four main issues in three hand preference groups. These main issues are time, distance, success and collision. The handedness distributions of Hacettepe participants and Atılım participants are respectively given in Figure 4.2 and Figure 4.3.

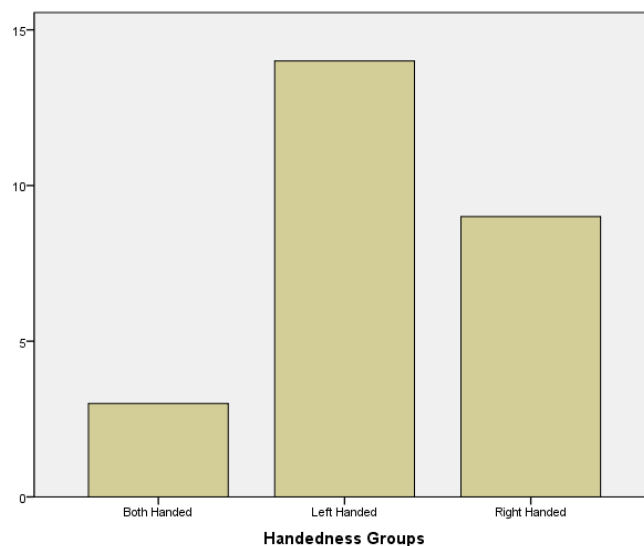


Figure 4.2 – The Handedness Distribution of Hacettepe University Participants

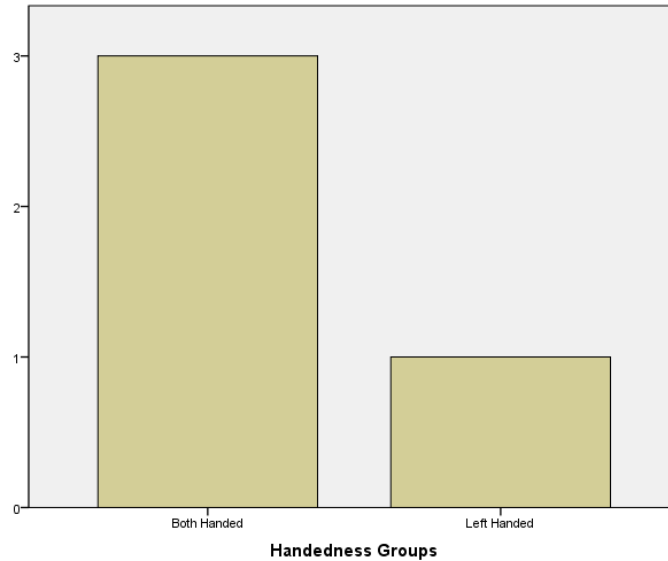


Figure 4.3 – The Handedness Distribution of Atılım University Participants

As seen from Figures 4.2 and 4.3 the handedness distribution of both groups (Atılım University and Hacettepe University) are different. Since the number of participants at the Atılım University is very limited, it cannot be generalized. However, this result shows that the handedness of different occupations can be used as a measure for educational purposes on skill-based training programs.

TIME Measure Analysis

The first main issue to explain is time: the task completion duration in seconds. In other words, time measure analysis has to be made in two dimensions: Left Hand, Right Hand. Each has to be analyzed in three dimensions. The first measure is for left-handed participants. The second is for right-handed participants and finally, the last one is for both-handed participants.

Understanding the Time Values of Left-Handed, Right-Handed and Both-Handed Participants

The time values of the participants while they were playing the Haptic Device scenario are given in Table 4.1. Time is the duration that takes from the start of the scenario to the end of the scenario with a single hand.

Table 4.1 –Time Values While Using Haptic Device Scenario

Hand		Left Hand	Right Hand
	Mean	3.2567	3.058
Both Handed	N	6	6
	Std. Deviation	1.3467	1.4759
	Mean	1.8660	2.343
Left Handed	N	15	15
	Std. Deviation	.2684	.3939
	Mean	2.5844	1.9200
Right Handed	N	9	9
	Std. Deviation	.4267	.4344
	Mean	2.3597	2.359
Total	N	30	30
	Std. Deviation	.8402	.8147

Table 4.2 shows the time values test of homogeneity of variances results. To understand the homogeneity of variances, Levene’s test should be made.

Table 4.2 –Test of Homogeneity of Variances of Time for Left and Right Hand

	Levene Statistic	df1	df2	Sig.
Left Hand Time	11.484	2	27	.000
Right Hand Time	16.916	2	27	.000

After running Levene’s test, as seen from Table 4.2 the time variances of left hand are not homogeneous with $F(2,27) = 11.484, p = .000 < .05$. Also, the time variances of right hand are not homogenous with $F(2,27) = 16.916, p = .000 < .05$ as seen from Table 4.2. So, the assumption of homogeneity of variances has been violated. Thus, ANOVA results should be taken into consideration to understand whether there is a significant difference between the mean of the groups.

Table 4.3 –ANOVA Results for Time

		Sum of Squares	df	Mean Square	F	Sig.
Left Hand Time	Between Groups	8.938	2	4.469	10.460	.000
	Within Groups	11.536	27	.427		
	Total	20.473	29			
Right Hand Time	Between Groups	4.673	2	2.336	4.328	.023
	Within Groups	14.574	27	.540		
	Total	19.247	29			

Table 4.3 shows that time of left hand and right hand are significant at the $p < .05$ level since $F(2,27) = 10.46$, $p = .000$ and $F(2,27) = 4.33$, $p = .023$ for ANOVA test. So, left hand time and right hand time are statistically different. To understand the groups, which are significantly different, Tamhane results are taken into account. Tamhane is one of the methods used in analyzing post-hoc test results when the variances of groups are not homogenous. Tamhane results indicate that with their left hand, the left-handed participants in average ($M=1.87$, $SD= 0.268$) spend significantly less time when compared with the right-handed participants ($M=2.58$, $SD= 0.427$) with $F(2,27) = .72$, $p = .02 < .05$. Table 4.4 shows the Tamhane results.

Table 4.4 –Post Hoc Test Results for Time While Using Haptic Device Scenario

Tamhane							
Dependent Variable	(I) Handedness	(J) Handedness	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Left Hand Time	Both	Left	1.3907	.5542	.149	-.5326	3.3139
		Right	.6722	.5679	.633	-1.2250	2.5694
	Left	Both	-1.3907	.5542	.149	-3.3139	.5326
		Right	-.7184*	.1583	.002	-1.1578	-.2791
	Right	Both	-.6722	.5679	.633	-2.5694	1.2250
		Left	.7184*	.1583	.002	.2791	1.1578
Right Hand Time	Both	Left	.7157	.6111	.644	-1.3836	2.8149
		Right	1.1383	.6197	.317	-.9451	3.2217
	Left	Both	-.7157	.6111	.644	-2.8149	1.3836
		Right	.4227	.1770	.087	-.0501	.8954
	Right	Both	-1.1383	.6197	.317	-3.2217	.9451
		Left	-.4227	.1770	.087	-.8954	.0501

*. The mean difference is significant at the 0.05 level.

The mean bar chart with standard error of left hand time according to handedness groups can be seen in Figure 4.4.

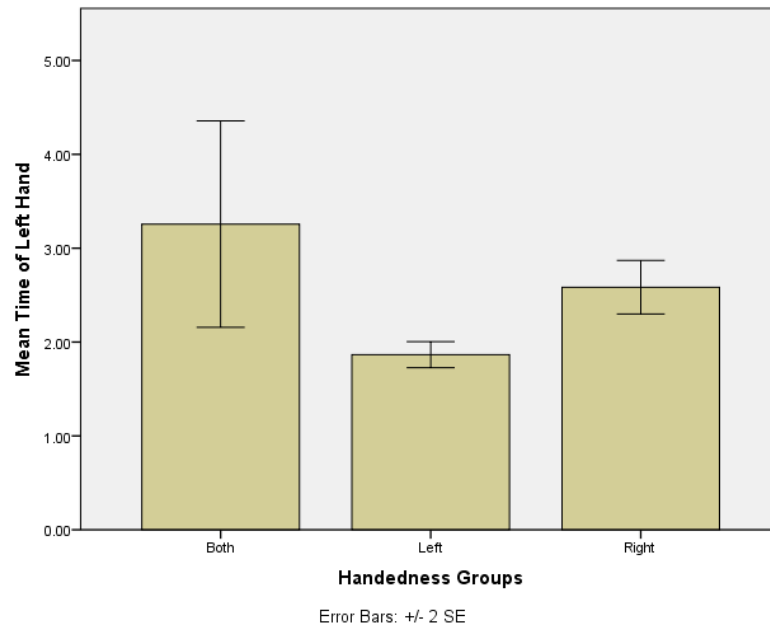


Figure 4.4 – Bar Chart with Mean and Standard Error of Left Hand Time versus Handedness Groups

Understanding Left Hand and Right Hand Time Values of Each Group

Further analyses are conducted to understand if there is a significant difference between left-hand performance and right-hand performance of each groups.

Time Analysis of Left-Handed Participants

In order to understand if there is a significant difference between their left-hand and right-hand performance of the left-handed participants a paired-sample t-test was conducted. The statistical information of left-handed participant is given in Table 4.5.

Table 4.5 – Paired Samples Statistics for Left-Handed Participants

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Left Hand Time	1.8660	15	.2684	.0693
	Right Hand Time	2.3427	15	.3939	.1017

Table 4.6 – Paired Samples Test Result for Left-Handed Participants

		Paired Samples Test					t	df	Sig. (2-tailed)
		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Left Hand Time – Right Hand Time	-.4767	.3467	.0895	-.6687	-.2847	-5.324	14	.000

According to these results, the left-handed participants spend significantly less time with their left hand ($M = 1.87, SD = .27$) when compared with their right hand ($M = 2.34, SD = 2.34$); $t(14) = -5.325, p = 0.000$. Paired samples test result for time of left-handed participant is shown in Table 4.6. The bar chart with standard error of left hand and right hand time for left handed participants is shown in Figure 4.5.

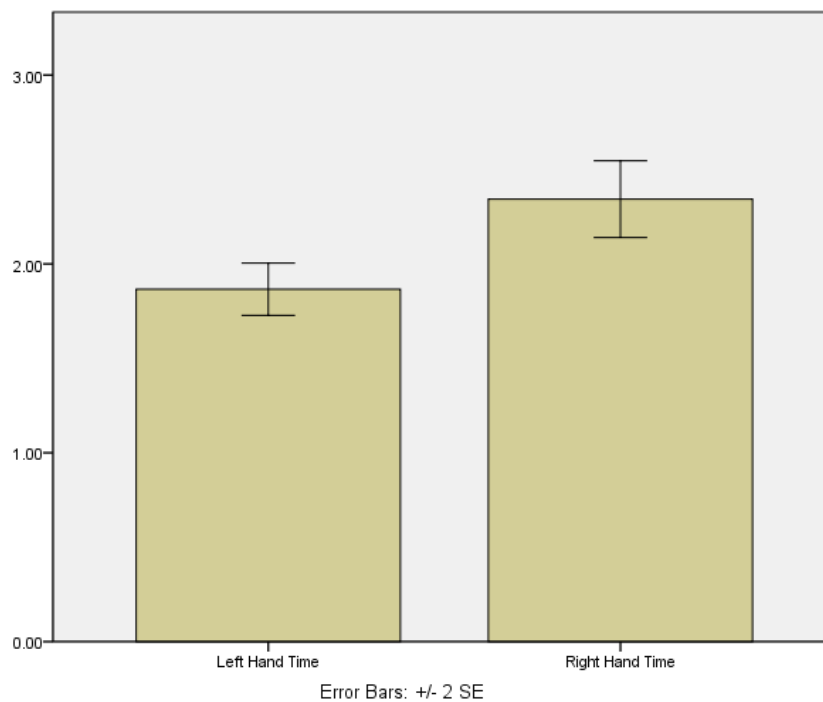


Figure 4.5 – Bar Chart with standard error of Left Handed Participants

Time Analysis of Right-Handed Participants

The statistical information of right-handed participant is given in Table 4.7. Right-handed people spend statistically less time with their right hand ($M = 1.92, SD = .43$)

when compared with their left hand ($M=2.58, SD = .43$); $t(9) = 5.219, p = .001$. The paired samples test results are shown in Table 4.8.

Table 4.7 – Paired Samples Statistics for Right-Handed Participants

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Left Hand Time	2.5844	9	.4270	.1423
	Right Hand Time	1.9200	9	.4344	.1448

Table 4.8 – Results of Paired Sample Test for Right-Handed Participants

Paired Samples Test							t	df	Sig. (2-tailed)
		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Left Hand Time - Right Hand Time	.6644	.3820	.1273	.3708	.9581	5.219	8	.001

The bar chart with standard error of left hand and right hand time for right-handed participants is shown in Figure 4.6.

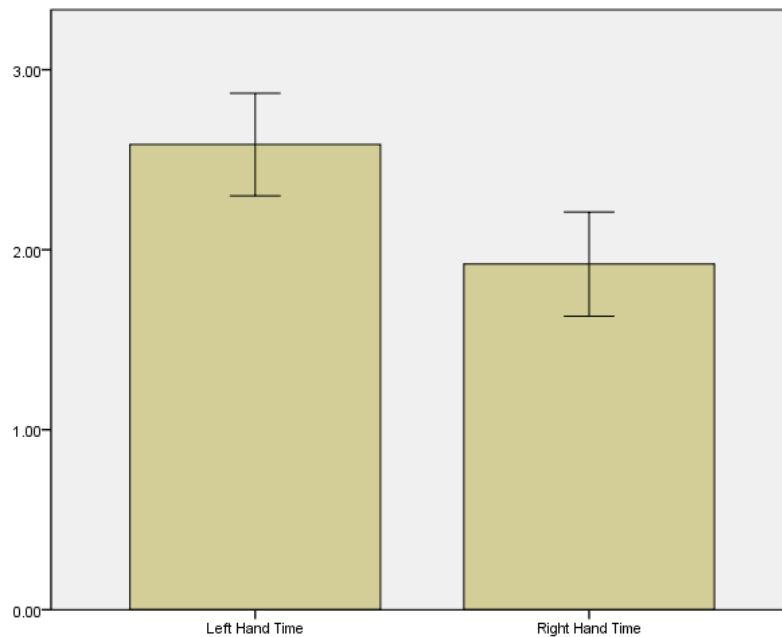


Figure 4.6 – Bar Chart with standard error of Right Handed Participants

Time Analysis of Both-Handed Participants

When the time of left hand and time of right hand are compared to understand the performance differences of both-handed participants, it is needed to make a paired samples test. Paired samples statistics for both-handed participants is shown in Table 4.9.

Table 4.9 – Paired Samples Statistics for Both-Handed Participants

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Left Hand Time	3.2567	6	1.3467	.5498
	Right Hand Time	3.0583	6	1.4759	.6025

Table 4.10 – Results of Paired Samples Test for Both-Handed Participants

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Left Hand Time – Right Hand Time	.1983	.6672	.2724	-.5018	.8985	.728	5	.499

There is no significant difference between time of left hand ($M = 3.26$, $SD = 1.35$) and time of right hand ($M = 3.06$, $SD = 1.48$); $t(5) = .728$, $p = .499$, as seen in 4.10.

DISTANCE Measure Analysis

The second subject to discuss is distance. The mean and standard deviation among groups are given in Table 4.11.

Table 4.11 –Distance Values while Using Haptic Device Scenario

Handedness		Left	Right
Both Handed	Mean	100913.4065	87630.3352
	Std. Deviation	28415.2454	24504.6891
Left Handed	Mean	62392.5216	94727.9680
	Std. Deviation	23473.1349	33286.4340
Right Handed	Mean	115640.1056	68444.7278
	Std. Deviation	37431.5489	16794.7804
Total	Mean	86070.9738	85423.4694
	Std. Deviation	37398.4859	29180.2104

Understanding the Distance Values of Left-Handed, Right-Handed and Both-Handed Participants

Table 4.12 –Test of Homogeneity of Variances for Distance Values

	Levene Statistic	df1	df2	Sig.
Left Hand Distance	.652	2	27	.529
Right Hand Distance	1.569	2	27	.227

Table 4.12 shows the distance test of homogeneity of variances results. To understand the homogeneity of variances, Levene’s test should be done. After performing Levene’s test, as seen from Table 4.12 the variances are not significantly different with $F(2,27) = .65, p = .52 > .05$ and $F(2,27) = 1.57, p = .23 > .05$. So, the variances of groups are homogenous with 95% confidence level. According to ANOVA table as seen in Table 4.13, there was a significant difference between groups since $F(2,27) = 10.35, p = .000 < .05$. In order to understand the relationships of groups, the results of Tukey HSD are taken into consideration. Tukey HSD comparison is used because the variances of groups are homogenous.

Table 4.13 –ANOVA Results for Distance Values

		Sum of Squares	df	Mean Square	F	Sig.
Left Hand Distance	Between Groups	17600825304.536	2	8800412652.268	10.349	.000
	Within Groups	22959930359.087	27	850367791.077		
	Total	40560755663.623	29			
Right Hand Distance	Between Groups	3922325955.701	2	1961162977.851	2.549	.097
	Within Groups	20770729801.303	27	769286288.937		
	Total	24693055757.004	29			

As seen on Table 4.14, the results of Tukey HSD test indicated that the left hand distance of both-handed participants ($M = 100913.41$, $SD = 28415.25$) was significantly higher than that of left handed participants ($M = 62392.52$, $SD = 23473.14$), $F(2,27) = 10.35$, $p = .000 < .05$.

Additionally, post hoc comparisons using the Tukey HSD test indicated that the left hand distance of left-handed participants ($M = 62392.52$, $SD = 23473.14$) was also significantly less than that of the right-handed participants ($M = 115640.11$, $SD = 37431.54$), $F(2,27) = 10.35$, $p = .000 < .05$.

In order to understand the statistical significance of right hand distance, ANOVA result should be read. There was no significant effect of right hand distance values among right-handed, left-handed and both-handed participants, $F(2,27) = 2.549$, $p = .097 > .05$

Table 4.14 – Post Hoc Test Results for Distance Values

Tukey HSD							
Dependent Variable	(I) Handedness	(J) Handedness	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Left Hand Distance	Both	Left	38520.8849*	14086.1333	.028	3595.4768	73446.2930
		Right	-14726.6991	15369.2315	.609	-52833.4434	23380.0453
	Left	Both	-38520.8849*	14086.1333	.028	-73446.2930	-3595.4768
		Right	-53247.5840*	12295.3852	.001	-83732.9794	-22762.1885
	Right	Both	14726.6991	15369.2315	.609	-23380.0453	52833.4434
		Left	53247.5840*	12295.3852	.001	22762.1885	83732.9794
Right Hand Distance	Both	Left	-7097.6328	13397.7660	.857	-40316.2909	26121.0252
		Right	19185.6074	14618.1612	.401	-17058.9200	55430.1348
	Left	Both	7097.6328	13397.7660	.857	-26121.0252	40316.2909
		Right	26283.2402	11694.5290	.081	-2712.3817	55278.8621
	Right	Both	-19185.6074	14618.1612	.401	-55430.1348	17058.9200
		Left	-26283.2402	11694.5289	.081	-55278.8621	2712.3817

*. The mean difference is significant at the 0.05 level.

The bar chart with standard error of left hand distance according to handedness groups can be seen in Figure 4.7.

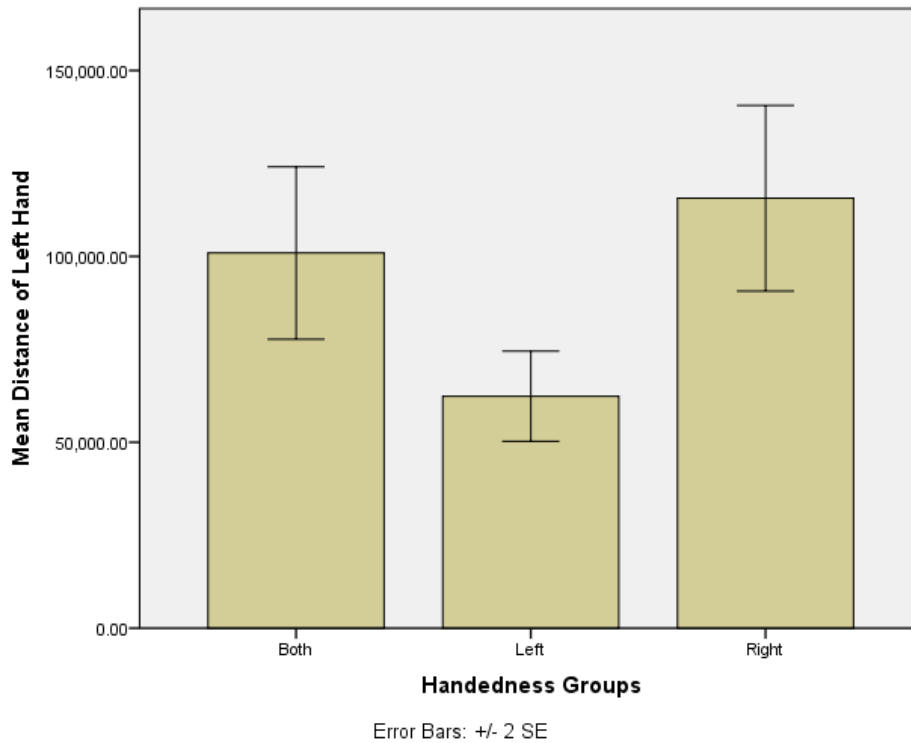


Figure 4.7 – Bar Chart with Mean and Standard Error of Left Hand Distance versus Handedness Groups

Understanding Left Hand and Right Hand Distance Values of Each Group

Distance Analysis of Left-Handed Participants

When distance measure of left-handed participants is analyzed, paired samples test helps us. The paired samples statistics are given in Table 4.15.

Table 4.15 – Paired Samples Statistics for Analyzing Distance Values of Left Handed Participants

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Left Hand Distance	62392.5216	15	23473.1349	6060.7374
	Right Hand Distance	94727.9680	15	33286.4340	8594.5203

The paired-sample t-test results show that left-handed people move significantly shorter paths with their left hand ($M = 62392.52$, $SD = 23473.13$) when compared with their right hand ($M = 94727.97$, $SD = 33286.43$); $t(14) = -7.232$, $p = .000$. The results of paired samples test for analyzing distance values of left-handed people are shown in Table 4.16. The bar chart with standard error for distance values of left-handed people is given in Figure 4.8.

Table 4.16 – Results of Paired Samples Test for Analyzing Distance Values of Left-Handed Participants

Paired Samples Test									
		Paired Differences				t	df	Sig. (2-tailed)	
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Left Hand Distance -	-32335.4464	17316.9017	4471.2048	-41925.2269	-22745.6659	-7.232	14	.000
	Right Hand Distance								

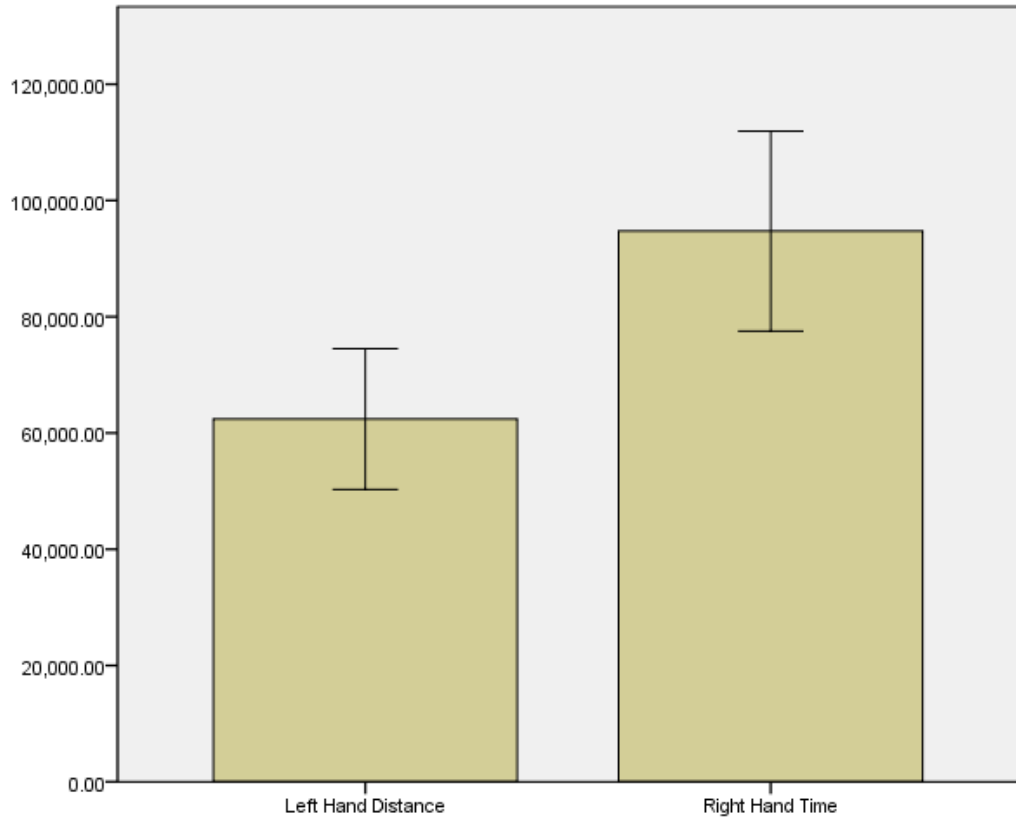


Figure 4.8 – Bar Chart with Standard Error for Distance Values for Left-Handed Participants

Distance Analysis of Right-Handed Participants

In order to understand the performance differences on left and right hand for distance measure for right-handed participants. It is needed to perform a paired samples test. The paired samples statistics are given in Table 4.17.

Table 4.17 –Paired Samples Statistics for Analyzing Distance Values of Right Handed Participants

Paired Samples Statistics					
	Mean	N	Std. Deviation	Std. Error Mean	
Pair 1	Left Hand Distance	115640.1056	9	37431.5486	12477.1829
	Right Hand Distance	68444.7278	9	16794.7804	5598.2601

According to the paired-sample t-test results, the right-handed people move significantly shorter paths with their right hands ($M= 68444.73$, $SD = 16794.78$) when compared with their left hands ($M= 115640.10$, $SD = 37431.55$), $t(8) = 4.30$, p

= 0.03 as seen in Table 4.18. The bar chart with standard error for distance values of right-handed participants is given in Figure 4.9.

Table 4.18 – Results of Paired Samples Test for Analyzing Distance Values of Right-Handed Participants

		Paired Differences				t	df	Sig.
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference			(2-tailed)
					Lower	Upper		
Pair 1	Left Hand Distance – Right Hand Distance	47195.3778	32939.3282	10979.7761	21875.9687	72514.7868	4.298	8 .003

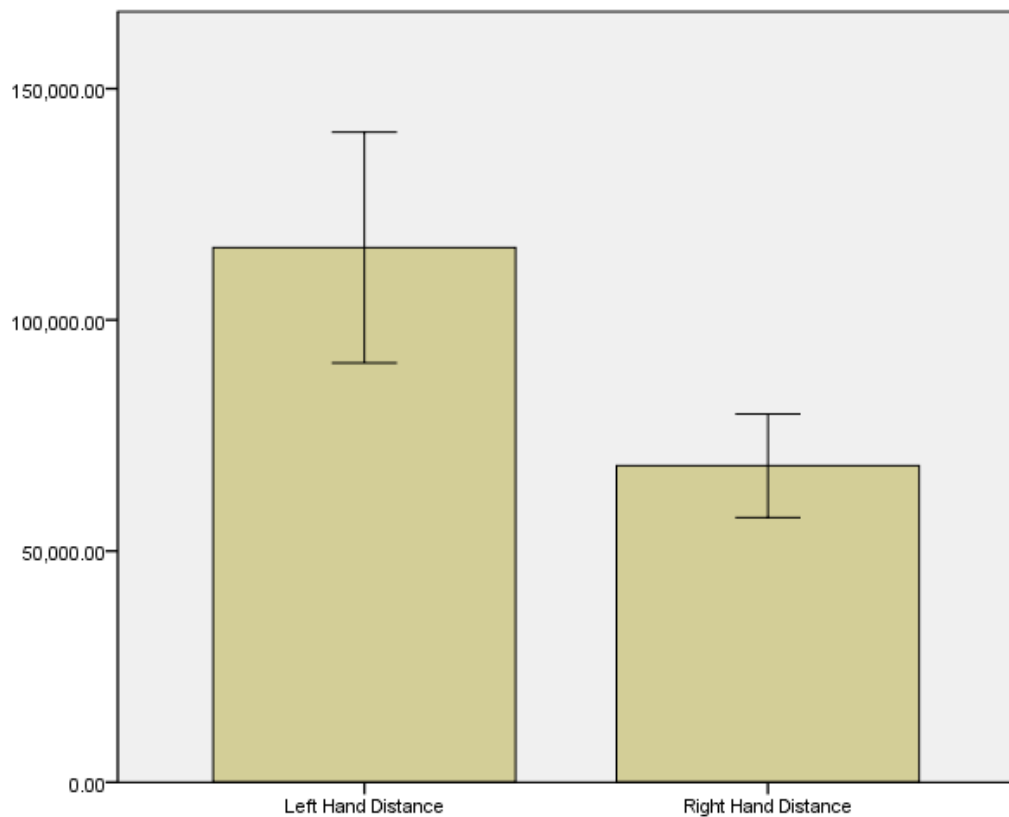


Figure 4.9 – Bar Chart with Standard Error for Distance Values for Right-Handed Participants

Distance Analysis of Both-Handed Participants

In order to understand the distance difference of left hand and right hand of both handed participants, we have to run a paired samples test. The statistical values for distance values of both handed participants are given in Table 4.19.

Table 4.19 –Paired Samples Statistics for Analyzing Distance Values of Both Handed Participants

		Paired Samples Statistics			
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Left Hand Distance	100913.4065	6	28415.2454	11600.4754
	Right Hand Distance	87630.3352	6	24504.6891	10003.9974

Table 4.20 –Paired Samples Test Results for Analyzing Distance Values of Both Handed Participants

		Paired Samples Test					t	df	Sig. (2-tailed)
		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Left Hand Distance – Right Hand Distance	13283.0713	14125.9988	5766.9149	-1541.2552	28107.3979	2.303	5	.069

There is no statistical difference between left hand distance ($M = 100913.407$, $SD = 28415.25$) and right hand distance ($M = 87630.34$, $SD = 24504.69$) of both-handed participants $t(5) = 2.303$, $p = .069$. Table 4.20 shows the results of paired samples test.

SUCCESS Measure Analysis

The third subject is success. The descriptive values for three handedness groups are given in Table 4.21.

Understanding the Success Values of Left-Handed, Right-Handed and Both-Handed Participants

Table 4.21 –Success Values While Using Haptic Device Scenario

Handedness		Left	Right
Both Handed	Mean	.8500	.8167
	Std. Deviation	.3209	.2858
Left Handed	Mean	1.0000	.9680
	Std. Deviation	.0000	.0692
Right Handed	Mean	.9778	1.0000
	Std. Deviation	.0441	.0000
Total	Mean	.9633	.9473
	Std. Deviation	.1474	.1449

Table 4.21 shows mean and standard deviation of success according to handedness groups. For right handed and left handed groups, the success ratios of non-dominant hand are compared. It is seen that the right-handed participants are more successful ($M = .98, SD = .044$) than left handed participants ($M = .97, SD = .69$) when the non-dominant hand is used.

Table 4.22 –Test of Homogeneity of Variances for Hand Success

	Levene Statistic	df1	df2	Sig.
Left Hand Success	11.673	2	27	.000
Right Hand Success	40.288	2	27	.000

In order to understand the homogeneity of variances, Levene statistic is applied. According to Table 4.22, Levene statistic stated that left hand success is significant since $F(2,27) = 11.67, p = .000 \leq .05$. Moreover, right hand success is also significant since $F(2,27) = 40.27, p = .000 \leq .05$. So the assumption of homogeneity of variances has been broken for both. As a result of this, ANOVA table has to be

analyzed in order to understand whether there is a significant difference between the mean of the groups.

According to the ANOVA table, left hand success is not statistically significant between groups at 95% confidence interval since $F(2,27) = 2.522$, $p = .099$. So, there is no effect of left hand success between right, left and both handed participants. On the other hand, right hand success was statistically significant between groups since $F(2,27) = 3.8$, $p = .035 < .05$. ANOVA results of Left and Right Hand success are seen in Table 4.23. In order to understand the relationship between groups, Tamhane results should be taken into consideration because the assumption of homogeneity of variances has been violated.

Table 4.23 – ANOVA Results for Hand Success

		Sum of Squares	df	Mean Square	F	Sig.
Left Hand Success	Between Groups	.099	2	.050	2.522	.099
	Within Groups	.531	27	.020		
	Total	.630	29			
Right Hand Success	Between Groups	.134	2	.067	3.800	.035
	Within Groups	.475	27	.018		
	Total	.609	29			

Table 4.24 shows the post hoc test results using Tamhane. Right hand success Tamhane results state that there is no statistically significant difference between handedness groups (right, left and both-handed participants) for right hand success.

Table 4.24 – Post Hoc Test Results for Hand Success

Dependent Variable: Right Hand Success
Tamhane

(I) Hand	(J) Hand	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Both	Left	-.1513	.1180	.584	-.5584	.2558
	Right	-.1833	.1167	.442	-.5938	.2271
Left	Both	.1513	.1180	.584	-.2558	.5584
	Right	-.0320	.0179	.259	-.0804	.0164
Right	Both	.1833	.1167	.442	-.2271	.5938
	Left	.0320	.0179	.259	-.0164	.0804

COLLISION Measure Analysis

The last but not least issue to be discussed is collision. The collision values of the participants while they are using the Haptic Scenario are given in Table 4.25.

Table 4.25 –Collision Values While Using Haptic Device Scenario

Handedness		Left	Right
Both Handed	Mean	.3500	.3500
	Std. Deviation	.2258	.2665
Left Handed	Mean	.2127	.3060
	Std. Deviation	.2330	.3922
Right Handed	Mean	.1411	.2433
	Std. Deviation	.1634	.1251
Total	Mean	.2187	.2960
	Std. Deviation	.2187	.3039

Table 4.26 – Test of Homogeneity of Variances for Collision

	Levene Statistic	df1	df2	Sig.
Left Hand Collision	.946	2	27	.401
Right Hand Collision	2.134	2	27	.138

Understanding the Collision Values of Left-Handed, Right-Handed and Both-Handed Participants

According to Levene’s test, as seen in Table 4.26, the variances of groups are homogenous at 95% confidence interval since $F(2,27) = .95, p = .40 > .05$ for left hand collision. Moreover, the variance of groups for right hand collision was also homogenous since $F(2,27) = 2.13, p = .14 > .05$. According to ANOVA results, left hand collision was not statistically significant between groups at 95% confidence interval since $F(2,27) = 1.74, p = .19 > .05$. Furthermore, right hand collision was not statistically significant between groups at 95% confidence interval since $F(2,27) = .23, p = .80 > .05$ as seen on Table 4.27. Due to the rejection of these hypotheses, there is no need to perform post-hoc tests. As a result of this, it can be understood that collision is not statistically significant between handedness groups (left, right and both-handed).

Table 4.27 –ANOVA Table for Error Ratio

		Sum of Squares	df	Mean Square	F	Sig.
Left	Between Groups	.158	2	.079	1.738	.195
Hand	Within Groups	1.228	27	.045		
Collision	Total	1.387	29			
Right	Between Groups	.044	2	.022	.225	.800
Hand	Within Groups	2.634	27	.098		
Collision	Total	2.678	29			

4.2 The results of Handedness Survey

Some single hand required tasks are asked to the participants. The tasks given in questionnaire are listed in the followings;

Which hand do you use?

- To write a legible text?
- To throw a ball to a target?
- To hold the racket while playing tennis?
- To strike a match?
- To cut with scissors?
- To thread a needle?
- To sweep with a broom?
- While using a shovel to move sand?
- To deal with playing cards?
- To hammer?
- To hold a toothbrush while brushing your teeth?
- To open a lid of a jar?

Moreover, if the answers of all these questions listed above are left/right, the participant has to write at least one action that he/she can do with his/her non-dominant hand. According to results of handedness questionnaire, the handedness distribution of writing a legible text, striking a match and dealing playing cards are the same. As a result of these three tests, 78% of the participants use their right hand and 17% of the participants are left-handed. The proportion of both-handed is 4%. The result of this question is given in Figure 4.10.

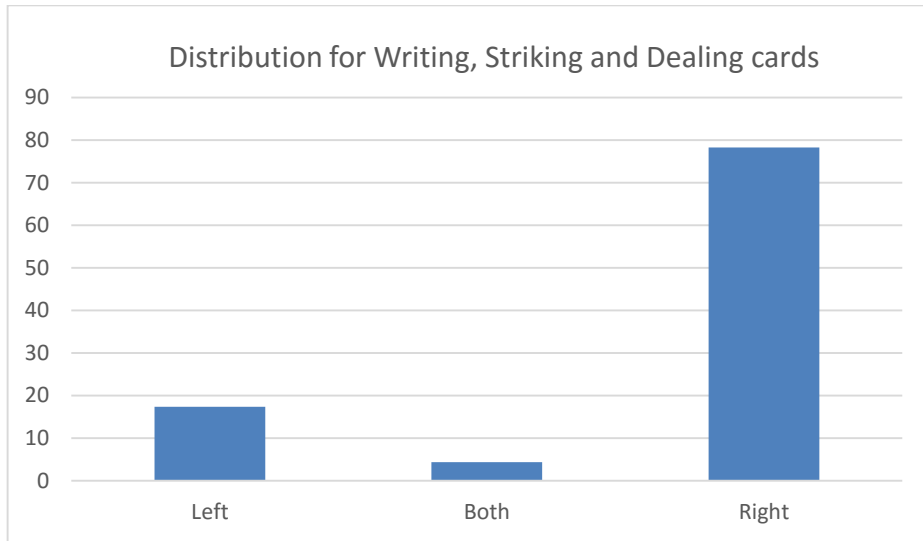


Figure 4.10 – Distribution for Writing, Striking and Dealing cards

While analyzing the throwing hand and passing string inside the needle, the results can be counted as follows; the ratio of right hand preference is 74%, the ratio of left hand preference is 17%. Finally, the 9% of participants use both hand. The result of throwing hand distribution is given in Figure 4.11.

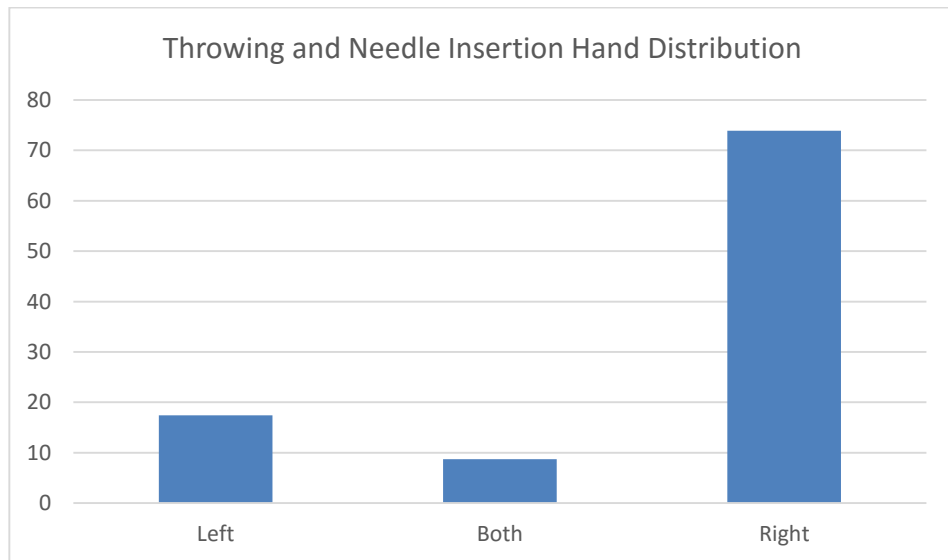


Figure 4.11 – Throwing and Needle Hand Distribution

Hand Distribution Racket Hand is given in Figure 4.12. No one can use both hands while playing tennis. 86% of the participants prefer right hand. On the other hand, 13% of the participants prefer left hand.

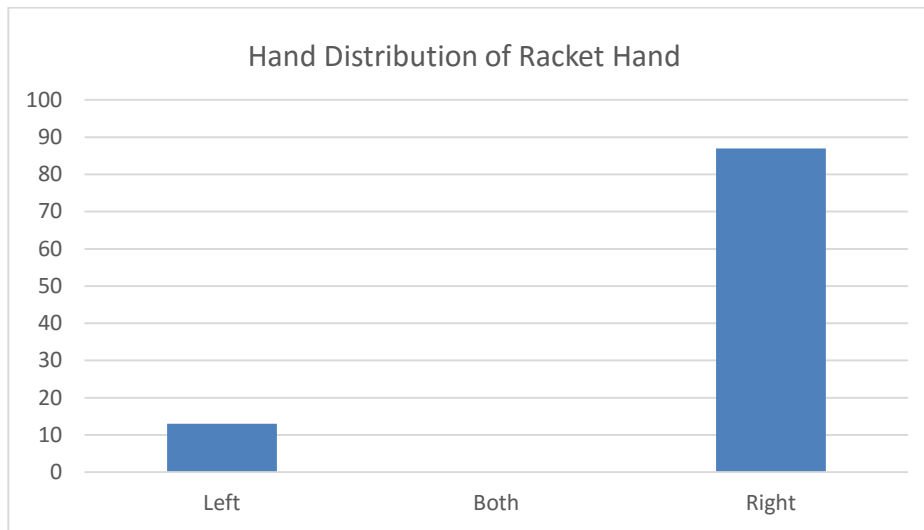


Figure 4.12 – Hand Distribution of Racket Hand

The scissors results indicate that the ratio of being right handed according to this test is 82%. Left-handed participants are 13% and both-handed rate is 4%. The results of using scissors are given in Figure 4.13.

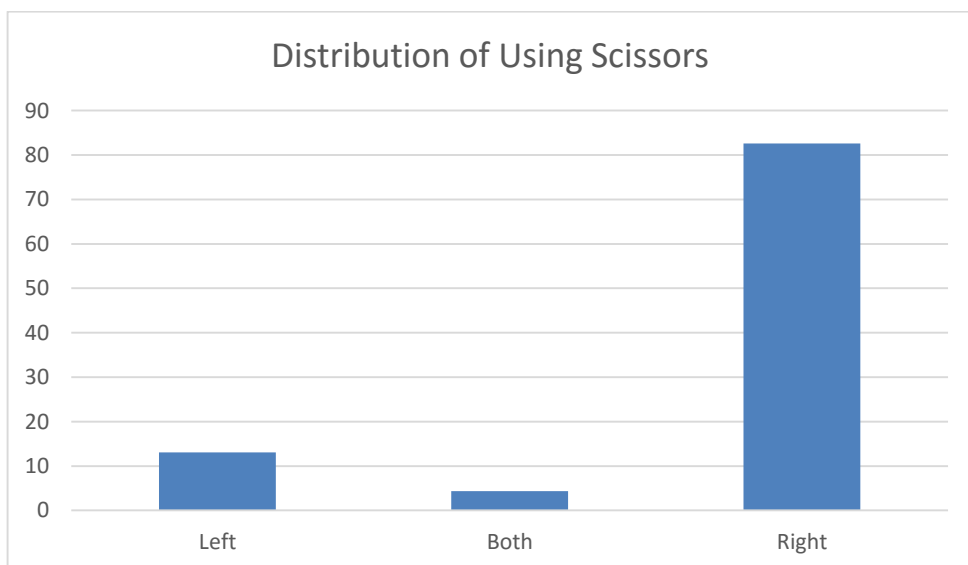


Figure 4.13 – Hand Distribution of Using Scissors

The results of hammering activity are given in Figure 4.18. As seen from Figure 4.14, the participants who can use hammer with both hand and left hand are equal with the same ratio of 13%. On the other hand, 74% of the participants hammer with their right hand.

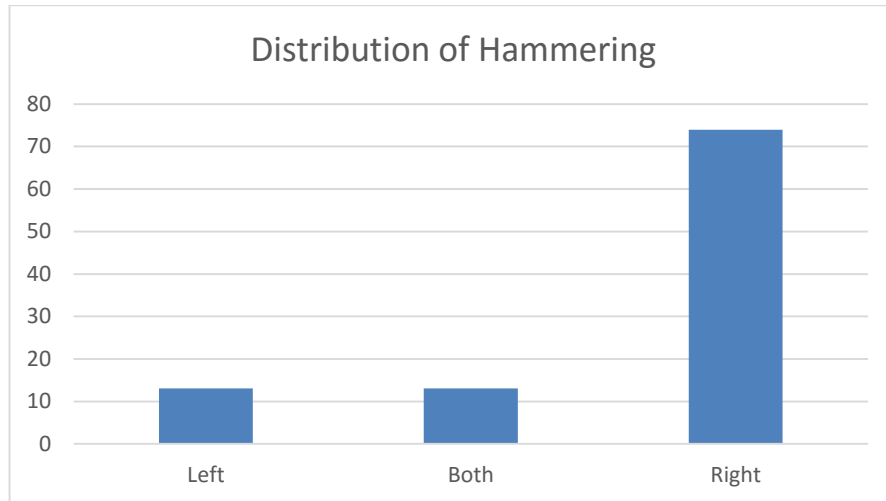


Figure 4.14 – The handedness distribution of Hammering

Figure 4.15 shows that 70% of participants use their right hand while brushing their teeth. The percentage of left-hand preference is 13. Finally, 17% of participants use both-hands while brushing teeth without no preference.

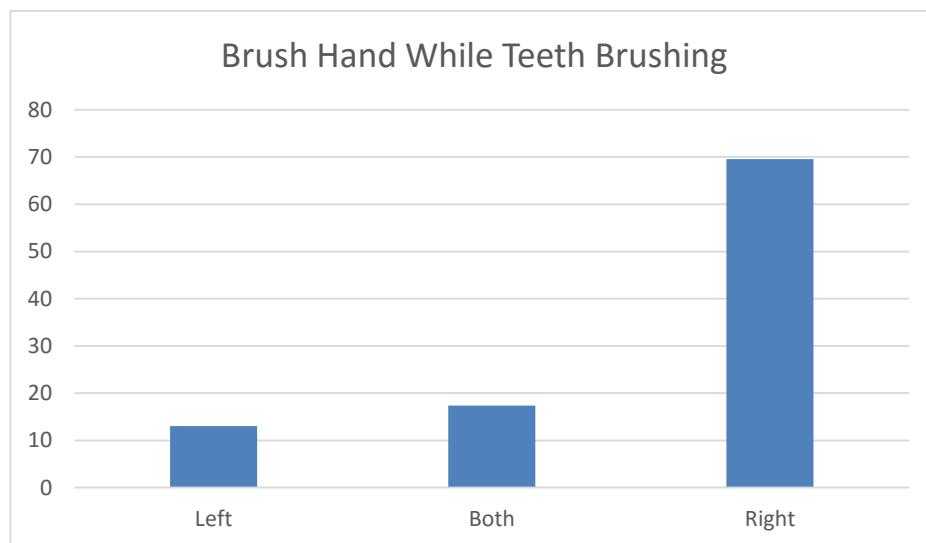


Figure 4.15 –The handedness distribution of Teeth Brush

The preferred hand while holding a broom and a shovel while moving sands are the same. The right-handed participants are 65%, 21% of the participants prefer their left hand and 13% of the participants can use both-hands without any preference. Figure 4.16 shows the related diagram.

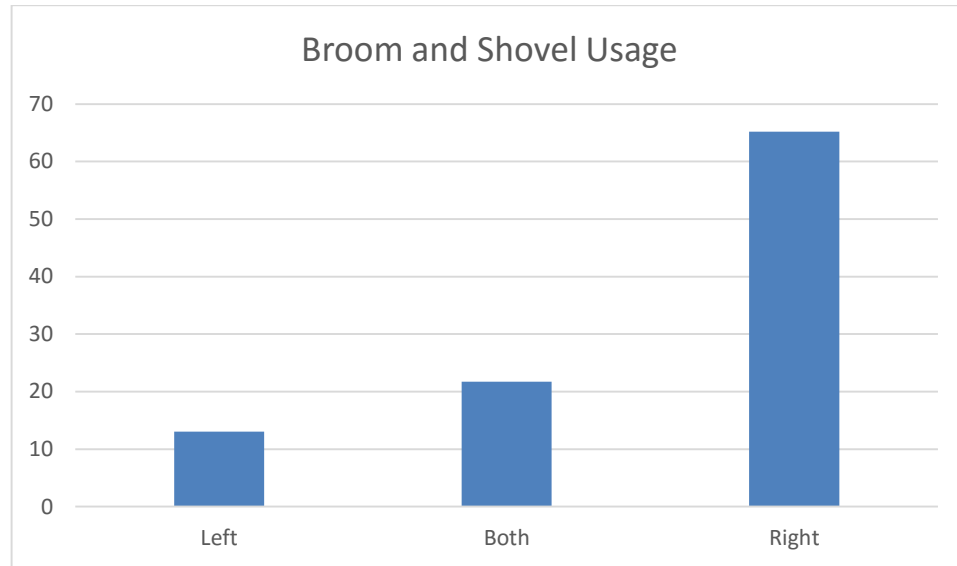


Figure 4.16 – Holding a broom while sweeping and a shovel while moving sands

When opening a can issue is taken into consideration, the handedness percentage changes are higher than the the others. 52% of the participants open a can with their right hand. On the other hand, 22% of the participants prefer to use their left hands while opening a can. Moreover, 26% of the participants open a can with both hands as seen in Figure 4.17.

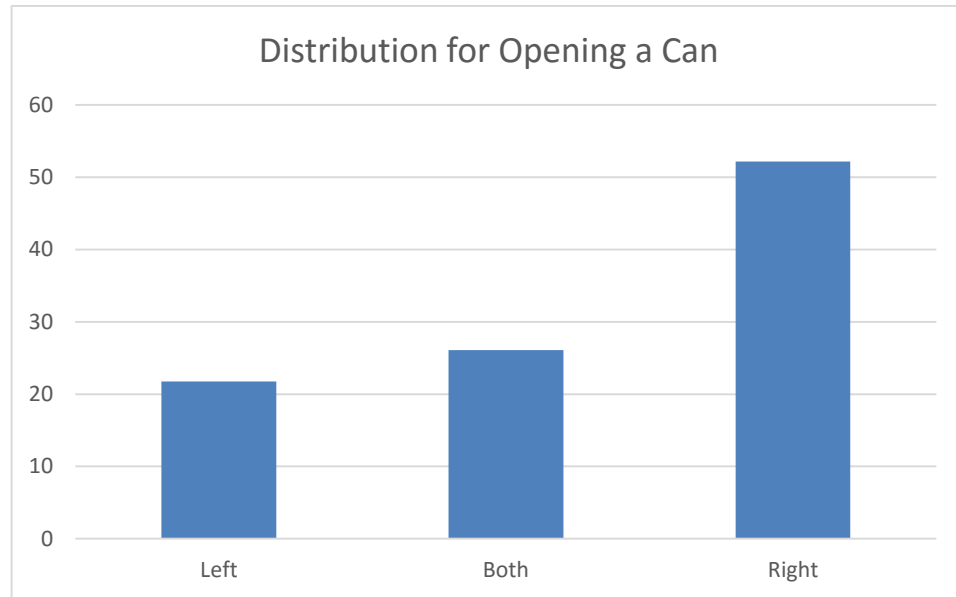


Figure 4.17 – Distribution for Opening a Can

In addition to this, if any participant performs all activities with his/her dominant hand, he/she was asked to write the tasks that he/she can do with his/her non-dominant hand. Participants can use their non-dominant hands while carrying a bag, using mobile phone, controlling TV by remote controller and making diagnosis.

As seen from the handedness questionnaire analyses, participants prefer different hand for different tasks. Hence it is hard to propose a standard measure from the handedness questionnaire analyses.

On the other hand the handedness analyses based on the haptic scenario provides an objective and standardized measure for understanding their hand skills based on the haptic controlled scenarios. Accordingly, we decided to use the handedness results from the haptic scenario measure in this study. We believe that the haptic-usage scenario can also be used as a standard measure for better understanding the right and left hand performance on specific tasks. The scenario can also be modified to address different skills by changing the tasks in the scenario according to the skills that required to be measured.

4.3 Understanding the Affect of Handedness on Performance

Using Both Hands in the Dark Scenario is used for the analysis of handedness of participants for this experiment. All participants of Using Haptic Device scenario

performed this scenario. However, eight of them couldn't finish this scenario because of some problems faced such as haptic device problems and health problems like dizziness and nausea. We excluded these people because of this.

TIME Measure Analyses

Time Values While Using Both Hands in the Dark Scenario are given in Table 4.28.

Table 4.28 –Time Values While Using Both Hands in the Dark Scenario

Handedness	Mean	Std. Deviation	N
Left	22.7064	7.3968	11
Right	28.3150	8.5154	8
Both	41.5740	18.7901	5
Total	28.5067	12.6682	24

Table 4.29 –Test of Homogeneity of Variances for Time

Time			
Levene Statistic	df1	df2	Sig.
2.713	2	21	.090

In order to understand the homogeneity of variances of groups for time measure, significance value of Levene's Statistic should be discussed. Table 4.29 shows that the variances of groups are homogenous at 95% confidence interval since $F(2,21) = 2.713$, $p = .090 > .05$. ANOVA results for time measure is shown in Table 4.30.

Table 4.30 –ANOVA Results for TIME Measure

Time					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1224.149	2	612.074	5.210	.015
Within Groups	2466.968	21	117.475		
Total	3691.117	23			

According to Table 4.31, left handed group performed the both handed task in a shorter time period ($M = 22.7$, $SD = 7.4$) when compared to the both handed group ($M = 41.6$, $SD = 18.8$), $F(2,21) = 5.21$, $p = .015$.

Table 4.31 – Post Hoc Results for Time

Dependent Variable: Time

Tukey HSD

(I) Handedness	(J) Handedness	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Both	Left	18.8676*	5.8459	.011	4.1327	33.6026
	Right	13.2590	6.1789	.105	-2.3154	28.8334
Left	Both	-18.8676*	5.8459	.011	-33.6026	-4.1327
	Right	-5.6086	5.0363	.516	-18.3029	7.0856
Right	Both	-13.2590	6.1789	.105	-28.8334	2.3154
	Left	5.6086	5.0363	.516	-7.0856	18.3029

*. The mean difference is significant at the 0.05 level.

Bar chart with mean and standard error of time between handedness groups is shown in Figure 4.18.

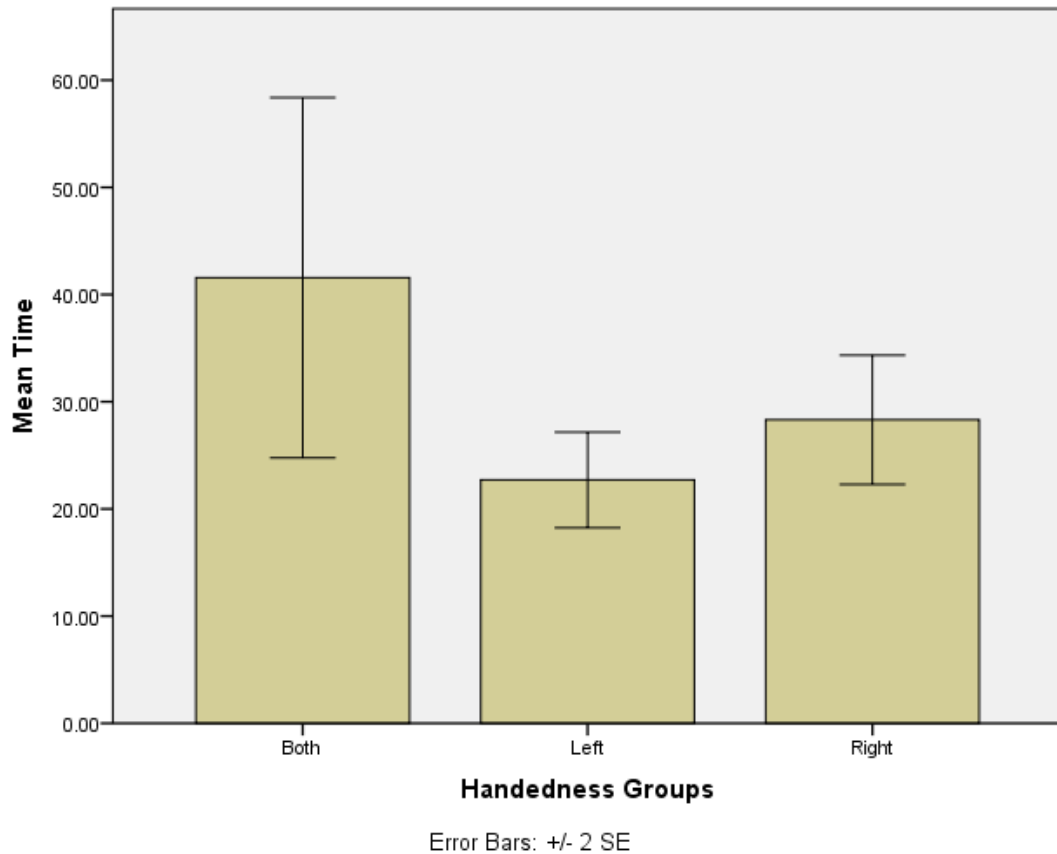


Figure 4.18 – Bar Chart with Mean and Standard Error of Time versus Handedness Groups

SUCCESS Measure Analyses

The second dimension to be explained is success. The measured success values are given in Table 4.32.

Table 4.32 – Success Values While Using Both Hands in the Dark Scenario

Success			
Handedness	Mean	N	Std. Deviation
Both	.7600	5	.1673
Left	.6545	11	.2979
Right	.6375	8	.2134
Total	.6708	24	.2440

Table 4.33 – Test of Homogeneity of Variances for Success

Success			
Levene Statistic	df1	df2	Sig.
1.041	2	21	.371

For understanding the homogeneity of variances of groups for success measure, significance value of Levene’s Statistic should be calculated. According to Table 4.33, the variances of groups are homogenous at 95% confidence interval since $F(2,21) = 1.04, p=.37 > .05$. To understand the statistically significance ANOVA results should be taken into consideration. As seen on Table 4.34, there was no statistical significance between groups for success measure at 95% confidence interval since $F(2,21) = .41, p = .67 > .05$. There is no need to perform post-hoc tests due to the rejection of this hypothesis.

Table 4.34 –ANOVA Results for Success

Success					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.052	2	.026	.411	.668
Within Groups	1.318	21	.063		
Total	1.370	23			

COLLISION Measure Analyses

Finally, collision is the last but not least dimension of this scenario to better understand the performance differences of handedness varieties. Table 4.35 shows the descriptive values for collision measure.

Table 4.35 – Collision Values While Using Both Hands in the Dark Scenario

Handedness	Mean	Std. Deviation	N
Right	2.7875	.6979	8
Both	3.4800	.7823	5
Left	2.0545	.4741	11
Total	2.5958	.8217	24

Table 4.36 –Test of Homogeneity of Variances for Collision

Collision			
Levene Statistic	df1	df2	Sig.
.667	2	21	.524

To understand the homogeneity of variances of groups for collision measure, Levene test should be performed. According to Test of Homogeneity of Variances For Collision Table 4.36, the variances of groups are homogenous at 95% confidence interval since $F(2,21) = 0.67, p=.52>.05$. To understand the statistical significance, ANOVA test also has to be taken into consideration. As seen on Table 4.37, there is statistical significance between groups for success measure at 95% confidence interval since $F(2,21) = 9.62 p = .001<.05$.

Table 4.37 –ANOVA Results for Collision

Collision					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7.426	2	3.713	9.621	.001
Within Groups	8.104	21	.386		
Total	15.530	23			

To understand the groups, which have statistically significant relationships, Post hoc comparison using Tukey HSD is run. Table 4.38 shows the post hoc test for collision. Tukey HSD stated collision of both-handed ($M = 3.48, SD = .79$) was significantly higher than that of left-handed participants ($M = 2.05, SD = .47$), $F(2,21) = 0.67, p=.52>.05$.

Moreover, Tukey HSD also indicated that collision of left-handed participants ($M = 2.05, SD = .47$) was significantly less than that of right-handed participants ($M = 2.79, SD = .70$), $F(2,21) = 0.67, p=.52>.05$.

Table 4.38 – Post Hoc Test Results for Collision

Dependent Variable: Collision

Tukey HSD

(I) Handedness	(J) Handedness	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Both	Left	1.4255*	.3351	.001	.5809	2.2700
	Right	.6925	.3542	.148	-.2001	1.5851
Left	Both	-1.4255*	.3351	.001	-2.2700	-.5809
	Right	-.7330*	.2887	.048	-1.4605	-.0054
Right	Both	-.6925	.3542	.148	-1.5851	.2001
	Left	.7330*	.2887	.048	.0054	1.4605

*. The mean difference is significant at the 0.05 level.

Bar Chart with Mean and Standard Error of collision between Handedness Groups is shown in Figure 4.19.

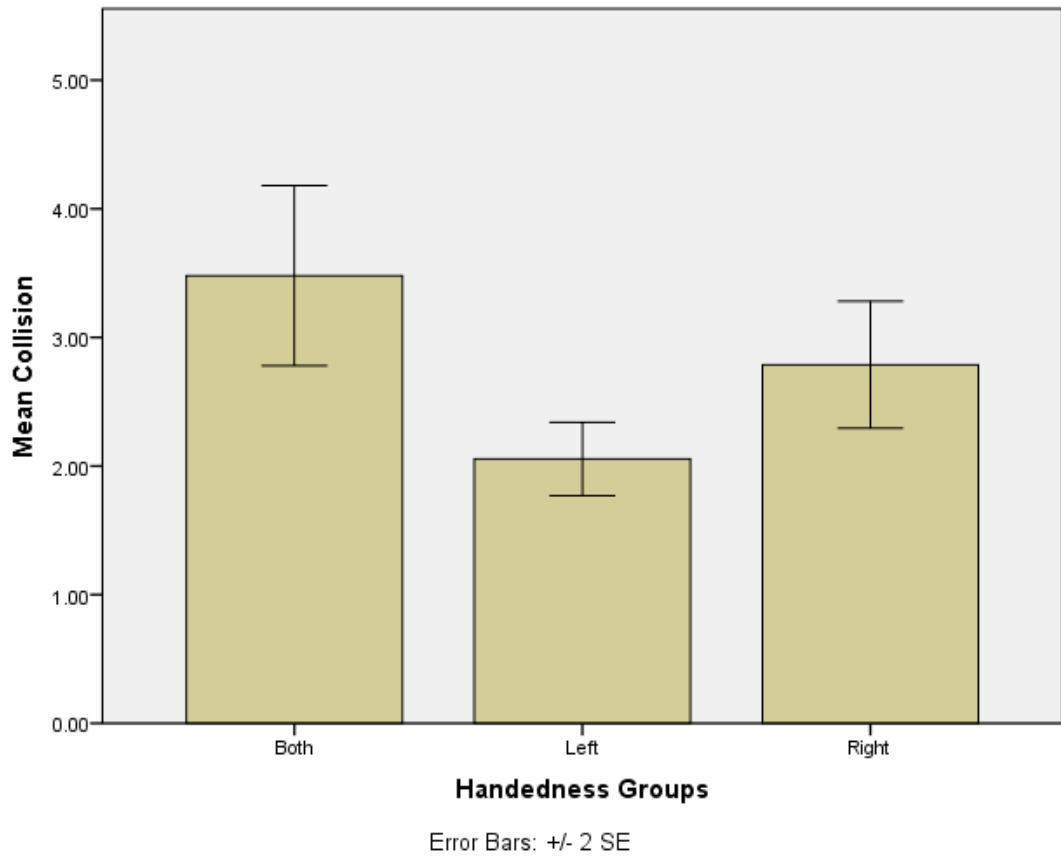


Figure 4.19 – Bar Chart with Mean and Standard Error of Collision between Handedness Groups

CHAPTER 5

DISCUSSIONS AND CONCLUSION

Two main research questions are set for this study. The first research question is:

“How to understand the handedness of participants in an objective way?”

In order to answer this research question, studies found in the literature have been analyzed. In the literature, there is no standardized measure to understand the handedness level of people. The only measure that we have found is the handedness questionnaire (see Appendix A). When the results of questionnaire called handedness survey is taken into consideration, the handedness of the participants cannot be classified according to their hand that they use for writing. The classification of handedness can be branched to many actions like Annett’s classification such as hammering, teeth brushing and striking a match [15]. Moreover, the results of this questionnaire supply Annett’s classification. We have applied this questionnaire to the participants of this study and we have seen that the results indicate different values for different tasks. Hence, we could not group the participants according to the handedness results of this survey. Then, in order to understand the handedness of participants a special scenario named as Using Haptic Device scenario is developed.

When the result of questionnaire and the result of using haptic device scenario are compared, it is seen that the handedness distributions of both cases do not support each other. The main reason of this is the professions of participants. Moreover, if a surgeon prefers one hand for writing, s/he has the ability to use both hands well. The handedness classification scenario “using haptic device” is an objective handedness classification method for surgical domain.

The Using Haptic Device scenario was performed two times by each participant, to understand the handedness of people. At the end of the Using Haptic Device scenario, the handedness distribution of participants was clearly understood. According to the performance of the participants in this scenario with their right hand and left hand, the participants are grouped in three (left-handed, right-handed and both-handed). Our handedness distribution results shows that 50% of the participants are left-handed, 30% of participants are right handed and 20% of the participants are both-handed. On the other hand, it is known that right-handedness is around 93% of the human population since historical times [6]. As a result of this, the handedness distribution of this study did not meet the actual handedness population. However, this solution may be the result of the participants of this study. The participants of this study were surgeons with a high ratio around 90%. As a matter of fact, it should not be forgotten that a surgeon needs to use his/her both hands equally well. The results of handedness questionnaire and the handedness distribution of using haptic device scenario are not in parallel because the results of questionnaire indicated that most of the participants perform all activities with their right hand. According to the answers of questionnaire, 73% of the participants use their right hand while performing single-handed tasks. On the other hand, 16% of the participants use their left hand. 11% of the participants are both-handed.

According to the comparisons between dominant hand and non-dominant hand in the literature, we also found similar results for Using Haptic Device. Hoffman stated that dominant hand is better than non-dominant hand in terms of speed and accuracy [49]. According to our results, the movement path of dominant hand is also shorter than non-dominant hand. This result is in parallel with the study done by Hoffmann in 1995 [49]. The performance differences that we have found between dominant and non-dominant hand can be listed as follows:

- Left handed people spend significantly less time and less distance with their left hand when compared with their right hand.
- Right handed people spend significantly less time and less distance with their right hand when compared with their left hand.
- The difference between left-handed and right-handed participants is that left-handed participants make less collisions (hits to the unexpected parts in the

simulation) with their dominant-hand than that of right-handed participants with their dominant-hand. This result is not in parallel with the study done by Hoffmann in 1995 [49]. Hoffman stated that right-handed people are significantly more successful than left-handed people when the performance of dominant hand is considered.

- The results of using haptic device scenario shows that left hand distance of both-handed participants was significantly higher than that of left handed participants. This finding is in parallel with the Uzoigwe's hypothesis [6]. Uzoigwe stated that both-handed people are more prone to make errors because they can think that they might have some doubts about performing the same with their right hand.
- According to Salvendy the right hand performance of left-handed people is better than the left hand performance of right-handed people [47]. However, we have found that non-dominant hand success of right-handed people is higher than the non-dominant hand performance of left-handed people.

As the handedness results conducted from using haptic device scenario performs supportive conclusion as the studies from the literature, this can be considered as a validation of the handedness measure proposed in this study. Accordingly, we can conclude that the Using Haptic Device scenario can be used as a measure to determine the handedness level of people.

On the other hand, the second research question of this study is set as below:

“What is the effect of handedness on both handed tasks?”

The scenario named “wire-haptic in dark” with both hands is designed to understand the effect of handedness on the performance in this scenario while performing two handed tasks. The handedness groups are organized according to using haptic device scenario performance results by means of time, distance, success and collision measures. Accordingly, the following results are found:

- The left handed group performed the both handed task in a shorter time period when compared with the both handed group.
- Both handed group make significantly more collision when compared with the left handed group. When the situation of both-handed participants is considered in both-handed task, our findings supports Uzoigwe's hypothesis

[6]. Uzoigwe stated that both-handed people are more prone to make mistakes [6]. The high collision can be the result of the undecided idea of which hands to use [6]. This situation is also possible for using Wire Haptic in Dark scenario because of thinking every time that what could happen if light and tool controls were changed and vice versa. For instance, a mixed-handed participant controls light with his/her right hand and controls tool with his/her left hand. S/he may think that s/he could control light better with his/her left hand and s/he could control tool better with his/her right hand. This is the problem that both-handed people faced.

- Right handed group make significantly more collision when compared with left-handed group.

In conclusion, we have found that there are performance differences between dominant and non-dominant hand and between single and both-handed tasks. This study also gives statistically significant differences among handedness groups (right, left and both handed). Moreover, we have found that preferred hand and hand skill level have an effect on performance. When the difficulties between two scenarios are compared, it is seen that the difficulty level of a task is also a factor of performance.

FUTURE WORK

Some properties of haptic devices were not implemented due to lack of information such as force-feedback. In both scenarios, the weight of tools is not implemented. In addition to this, participants of this study stated that there was a problem about depth perception. So, participants had problems with this in using both hands in the dark scenario. In future studies, if these problems are solved, the performance differences between dominant and non-dominant hand and the performance differences between right, left and both-handed participants will be understood easily. In order to understand the performance differences between groups (Atılım University and Hacettepe University), it is needed to increase the number of participants at Atılım University.

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APPENDICES

APPENDIX A – Handedness Survey

Katılımcı ID:

Ad- Soyad:

Aşağıdaki aktiviteleri gerçekleştirirken alışkanlık olarak hangi elinizi kullanmayı tercih ettiğinizi belirtiniz.

	Sağ	Sol	Her İkisi
Okunaklı bir yazı yazmak istediğinizde hangi elinizi kullanmayı tercih edersiniz?			
Bir hedefi topla vurmak istediğinizde hangi elinizi kullanmayı tercih edersiniz?			
Raketle oynanan sporlarda (tenis, squash, badminton gibi) raketi hangi elinizle tutarsınız?			
Kibrit çakmak için hangi elinizi kullanmayı tercih edersiniz?			
Makası hangi elinizle kullanmayı tercih edersiniz?			
İğne deliğinden iplik geçirirken hangi elinizi kullanmayı tercih edersiniz?			
Süpürgeyi hangi elinizle kullanmayı tercih edersiniz?			
Kürekle kum taşırken hangi elinizi kullanmayı tercih edersiniz?			
Oyun kartlarını hangi elinizle dağıtırsınız?			
Çivi çakmak için çekici hangi elinizle tutarsınız?			
Diş fırçasını hangi elinizle tutarsınız?			
Kavanozun kapağını açarken hangi elinizi kullanmayı tercih edersiniz?			

Eğer yukarıdaki **İŞLEMLERİN HEPSİ İÇİN SAĞ ELİNİZİ** kullanıyorsanız, **SOL ELİNİZİ** kullanarak yaptığınız herhangi bir işlem varsa yazınız.

Eğer yukarıdaki **İŞLEMLERİN HEPSİ İÇİN SOL ELİNİZİ** kullanıyorsanız, **SAĞ ELİNİZİ** kullanarak yaptığınız herhangi bir işlem varsa yazınız.

APPENDIX B –The original form of Handedness Survey

Handedness research

NAME _____ AGE _____ SEX _____

Were you one of twins, triplets at birth or were you single born?

*Please indicate which hand you habitually use for each of the following activities by writing **R** (for right), **L** (for left), **E** (for either).

Which hand do you use:

1. To write a letter legibly?
2. To throw a ball to hit a target?
3. To hold a racket in tennis, squash or badminton?
4. To hold a match whilst striking it?
5. To cut with scissors?
6. To guide a thread through the eye of a needle (or guide needle on to thread)?.....
7. At the top of a broom while sweeping?.....
8. At the top of a shovel when moving sand?
9. To deal playing cards ?
10. To hammer a nail into wood?
11. To hold a toothbrush while cleaning your teeth?
12. To unscrew the lid of a jar?

If you use the **RIGHT HAND FOR ALL OF THESE ACTIONS**, are there any one-handed actions for which you use the **LEFT HAND** ? Please record them here

If you use the **LEFT HAND FOR ALL OF THESE ACTIONS**, are there any one-handed actions for which you use the **RIGHT HAND**? Please record them here..